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BATTLE GROUP ORDNANCE AND FUEL LOGISTIC TASK MEASURES OF PERFORMANCE FOR THE UNIVERSAL NAVAL TASK LIST

by

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A set of well-defined and quantifiably justified Measures of Performance (MOPs) is required for the armament and fuel tasks of a Carrier Battle Group (CVBG) as described in the Universal Naval Task List (UNTL). Well-defined MOPs are required because the current UNTL contains MOPs that are not relevant for the Battle Group Commander to effectively evaluate task performance at the CVBG level. These MOPs are incorporated in the CVBG's training plan and provide the Battle Group Commander a method to evaluate the CVBG's level of ability to perform the necessary tasks. This thesis proposes 37 MOPs and an application to subjectively evaluate the MOPs to determine which ones are well defined. The application also objectively evaluates the MOPs to determine how well they collectively measure task performance. The proposed MOPs are derived from the task descriptions and objectives found in the UNTL. They are subjectively scrutinized using the twelve criteria required by the UNTL and objectively evaluated using correlation analysis. A simulation is developed for each task to provide the data for the objective analysis. The results indicate that 25 of the 37 proposed MOP's meet the required criteria of being well defined and useful in measuring task performance. Based upon the developed application, it is recommended that the Naval Doctrine Command consider the 25 MOPs for inclusion into its revised UNTL.

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BATTLE GROUP ORDNANCE AND FUEL LOGISTIC TASK MEASURES OF PERFORMANCE FOR THE UNIVERSAL NAVAL TASK LIST

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DISCLAIMER

The reader is cautioned that the computer program (simulation) developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the program is free of computational and logic errors, it cannot be considered validated. Any application of this program without additional verification is at the risk of the user.

TABLE OF CONTENTS

LIST OF ACRONYMS

BGCDR	Battle Group Commander
CNO	Chief of Naval Operations
COMDT USCG	Commandant, United States Coast Guard
CONREP	Connected Replenishment
CVBG	Carrier Battle Group
MET	Mission Essential Task
METL	Mission Essential Task List
MOE	Measure of Effectiveness
MOP	Measure of Performance
NMETL	Naval Mission Essential Task List
NTA	Navy Tactical
UNREP	Underway Replenishment
UNTL	Universal Naval Task List
VERTREP	Vertical Replenishment

EXECUTIVE SUMMARY

The U.S. Navy intends to improve the way its forces train for combat operations. A new approach to training has been adopted that uses the Universal Naval Task List (UNTL) to identify the tasks, conditions, and standards needed to develop Mission Essential Tasks (METs). METs are tasks deemed essential to accomplish the mission. The UNTL serves as a basis for process level modeling of naval task performance..

The UNTL is developed by Naval Doctrine Command and consists of tasks, conditions, and standards needed to perform in all areas of combat operations. When assigned a combat mission, a Battle Group Commander (BGCDR) uses the UNTL to determine (1) the tasks required of the Carrier Battle Group (CVBG) to execute the mission, (2) the conditions of the operating environment that may affect task performance, and (3) the standards required to evaluate how well the tasks are performed under the selected conditions.

Naval Doctrine Command is revising the UNTL to determine the standards required to assess how well CVBG tasks are performed. Those standards consist of measures of performance (MOP) and criteria used to assess the extent to which the standards are achieved. MOPs provide a dimension, capacity, or quantity description to a task to indicate how well a task is performed. The criteria are the acceptable levels of the MOP set by the BGCDR. There is a major problem, however: the CVBG's *Armament* and *Fuel* MOPs listed in the UNTL are ill defined. The CVBG is a tactical level organization, and the MOPs currently listed in the UNTL are focused on the strategic level.

The UNTL is divided into four levels of combat. Each level is divided into six mission objective categories. One of those categories

is *Perform Logistics and Combat Service Support*, which is further divided into thirteen sub-categories. The UNTL lists tasks and MOPs for each sub-category of every mission objective category. This thesis focuses on two of the thirteen sub-categories, namely, *Armament* and *Fuel*, because ordnance and fuel are the two most critical support elements in sustaining a CVBG. The present work determines (1) what MOPs can be well-defined for each task within the *Armament* and *Fuel* sub-categories, and (2) how well those MOPs measure task performance.

A five-step application is developed to define MOPs and determine how well they measure task performance. The application analyzes the components of the task to determine the specific measurements needed to evaluate the extent to which an operation's performance achieves criterion performance. Those specific measurements are quantifiable variables that comprise MOPs.

A qualitative analysis is conducted to determine if the MOPs can be defined for each task. The analysis uses twelve criteria listed in the UNTL to provide standards from which to conclude the validity of a well-defined MOP. These criteria are dichotomous; either a "yes" or "no" response. The resulting analysis provides well-defined MOPs for each *Armament* and *Fuel* task.

Each task is simulated to obtain values for the MOPs and MOEs. One analysis evaluates the MOPs and the task's defined measures of effectiveness (MOE) to examine how well the MOPs measure task performance. The values obtained for the MOPs are then compared with the values of their respective task's MOE to determine the extent to which the variables correlate. A high correlation suggests that an MOP is a strong indicator of task performance.

The results of the first analysis indicate that 37 MOPs (thirteen MOPs for the *Armament* tasks and twenty-four MOPs for the *Fuel* tasks)

are well defined, but only 25 meet the standards defined for the second analysis. Based on the application developed here, it is recommended that Naval Doctrine Command consider these 25 MOPs for inclusion into its revised UNTL. These MOPs can then be used to evaluate performance of CVBG armament and fuel task performance.

I. INTRODUCTION

A. OVERVIEW

The U.S. Navy along with the joint military community is working to improve the way the U.S. military forces prepare and train for combat operations. A new systematic approach to military combat training is evolving which uses the Universal Naval Task List (UNTL) and the Navy Mission Essential Task List (NMETL) concept to define mission tasks and their expected performance.

The UNTL is a single source document used by the Navy, Marine Corps, and Coast Guard to develop a Mission Essential Task List (METL). Mission Essential Tasks (METs) are tasks selected by the Battle Group Commander (BGCDR) which are taken from the UNTL and deemed essential to mission accomplishment. The NMETL is a list of the Navy's essential tasks. One of the keys to this new training approach is the concept of training to a list of METs. These concepts and those of the UNTL and NMETL are discussed later in Chapter II.

As head of the Carrier Battle Group (CVBG), the BGCDR uses the NMETL development process as a framework to quantify the level of work and the scope of effort needed for the CVBG to achieve specific mission objectives. As applied to CVBG training, the UNTL provides the common language that the BGCDR can use to document the command warfighting requirements as mission essential tasks.

The UNTL is divided into numerous categories and provides the task description, conditions, and standards needed to define a mission essential task. The standards are comprised of measures and criteria. A measure, also called a measure of performance (MOP), is a dimension, capacity, or quantity description related to a task. A criterion is a quantitative value on which a judgment or decision is based. This

thesis proposes and validates MOPs for the CVBG in two logistical areas: armament and fuel.

B. PROBLEM STATEMENT

One of the UNTL categories, the Navy tactical logistics category, or *NTA 4 Perform Logistics and Combat Service Support*, lists *Armament* and *Fuel* MOPs that are ill defined for the CVBG. Well-defined MOPs enable the BGCDR to develop mission essential tasks that effectively evaluate *Armament* and *Fuel* logistic task performance in CVBG exercises. This thesis addresses two questions. First, "What measures of performance can be well-defined for each task within the ordnance and fuel sub-categories of the *NTA 4 Perform Logistics and Combat Service Support* tactical level hierarchical listing?" Second, "How well do those measures of performance measure task performance?"

C. DESCRIPTION OF THE METHODOLOGY

A method is described in Chapter IV that derives variables that measure each task process. Those derivations are based upon the description of each task and the process involved to complete the task. The variables could be time, ratios, quantities, or some other quantifiable description required to measure the task's performance. Measures of performance for each task are then determined subjectively from those variables by validating them against twelve criteria that are defined in Chapter IV. This step answers the first question, "What MOPs can be well-defined for each task within the ordnance and fuel sub-categories?"

To determine how well the MOPs measure task performance, a quantitative analysis is conducted in Chapter V between the MOPs and the given measures of effectiveness (MOE) related to each task. A

spreadsheet based simulation model is designed for each task to obtain the data necessary to conduct the quantitative analysis. Correlation analysis determines the statistical relationship between an MOP and its MOE. This step answers the second question, "How well do the MOPs measure task performance?"

D. ORGANIZATION OF THESIS

This thesis is organized into six chapters. Chapter I provides an overview of the problem. Chapter II gives a description of the UNTL and the NMETL development process. Chapter III gives a description of CVBG ordnance and fuel logistic tasks used in the UNTL. Chapter IV describes the models used to obtain the CVBG fuel and ordnance measures. Chapter V provides the results of analysis. Chapter VI provides conclusions, recommendations, and areas for further study of the subject area.

II. BACKGROUND

This chapter describes the general development of the Navy Mission Essential Task List (NMETL), and specifically for the *armament* and *fuel* sub-categories of the logistic category in the tactical level of combat within the UNTL. The MOEs and MOPs are provided for each task.

A. THE NMETL DEVELOPMENT PROCESS

The Navy is developing a new training strategy that incorporates the UNTL into the process of defining CVBG tasks based upon mission requirements. Those CVBG tasks are used by BGCDRs to develop Naval Mission Essential Task Lists (NMETL), which, in turn, are used to define priorities in accomplishing the mission. The NMETL is the Navy's list of METs that supports CVBG training by providing a list of the BGCDR's prioritized requirements based upon assigned mission objectives. Figure 2.1 represents the flow of the NMETL development process taken from reference [1].

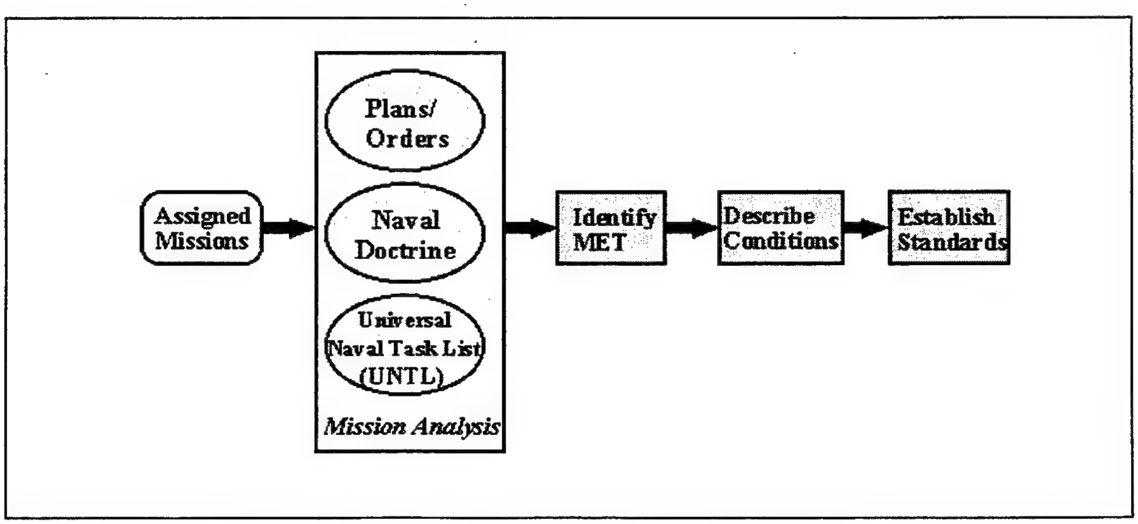

Figure 2.1 NMETL Development Process.

The NMETL development process is explained in reference [2] and is divided into three steps.

- Step 1. Identify the Mission Essential Task (MET).
- Step 2. Describe the Conditions.
- Step 3. Establish the Standards.

These steps guide the BGCDR through the analysis of assigned missions to arrive at a set of mission-based required capabilities. These required capabilities are expressed in terms of: (1) the tasks to be performed; (2) the conditions in which those tasks are to be performed; and (3) the standards to which that performance is achieved. The following definitions apply:

- Tasks. Events that enable the mission to be accomplished.
- Conditions. Variables of the operating environment that may affect task performance.
- Standards. Measures and criteria.
  - ♦ Measures provide a dimension, capacity, or quantity description to a task. "Measure" is used interchangeably with Measure of Performance (MOP).
  - ♦ Criteria describe the acceptable levels of performance.

Determining valid MOPs for the standards mentioned above is the focus of this thesis. In Step 1, the BGCDR examines the mission and applies the UNTL, doctrine, plans, and orders to identify the CVBG's naval METs; for example, a CVBG mission may require the UNTL task *Establish Water Space Management*. In Step 2, the BGCDR describes the conditions in which the tasks are to be performed; for example, the conditions may be in the *Ocean Waters-Atlantic*, under *High Shipping Presence*, and with *Full Maritime Superiority*. In Step 3, the BGCDR establishes standards for the NMETL based upon mission requirements;

for example, a standard may be the *Zero - Number of incidents of collision with underwater objects.*

B. ORGANIZATION OF THE UNTL

The UNTL lists all the combat associated tasks, conditions, and standards that are used in the NMETL development process described above. It is divided into four levels of combat: Strategic Theater (ST), Strategic National (SN), Operational (OP), and Tactical (NTA). These four levels are sub-divided into six mission objective categories that are depicted in figure 2.2.[Ref.1]

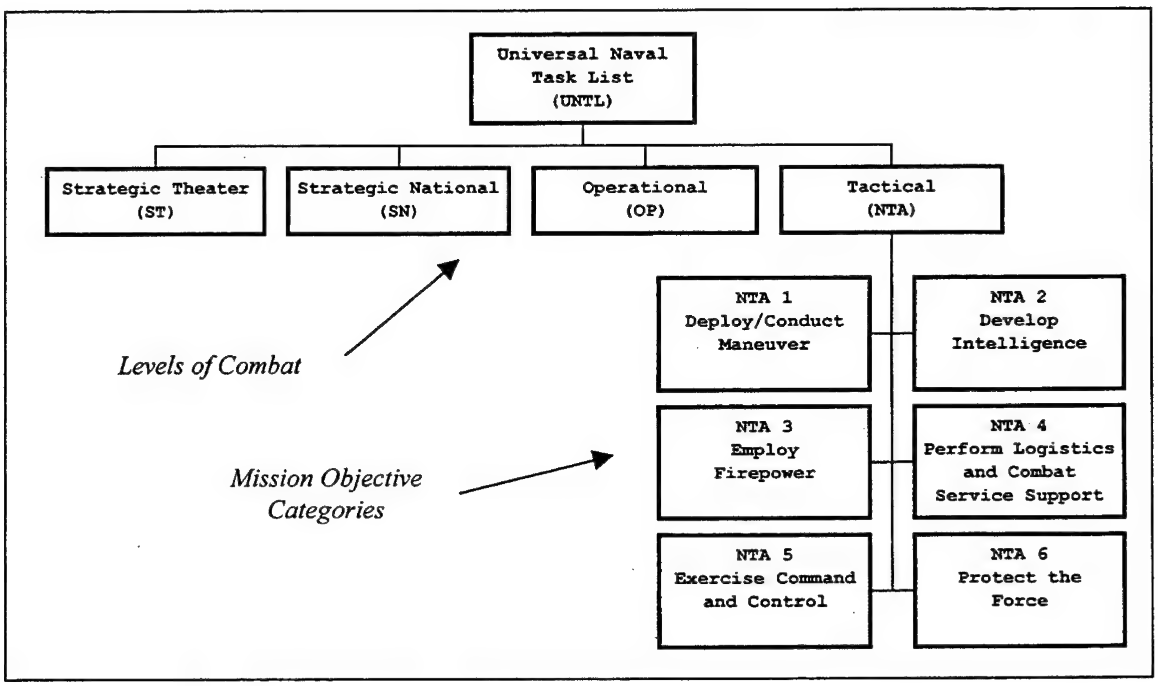

Figure 2.2 UNTL Hierarchical Listing.

These six mission objective categories are further divided into various sub-categories. This thesis focuses upon two sub-categories of the mission objective category, namely, *NTA 4 Perform Logistics and Combat Service Support.* Those two sub-categories are *NTA 4.1 Armament* and *NTA 4.2 Fuel.*

The sub-categories are assigned specific tasks that are determined by Naval Doctrine Command. There are three tasks in the *Armament* sub-category and five tasks in the *Fuel* sub-category. These tasks are listed below:

- NTA 4.1 Armament;
  - *NTA 4.1.1 Schedule/Coordinate Armament of Task Force;*
  - *NTA 4.1.2 Provide Munitions Management;*
  - *NTA 4.1.3 Provide Munitions, Pyrotechnics, and Specialty Items;*
- NTA 4.2 Fuel;
  - *NTA 4.2.1 Conduct Fuel Management;*
  - *NTA 4.2.2 Schedule/Coordinate Refueling;*
  - *NTA 4.2.3 Conduct Aerial Refueling;*
  - *NTA 4.2.4 Move Bulk Fuel;*
  - *NTA 4.2.5 Provide Packaged Petroleum Products.*

The UNTL describes each task of the *Armament* and *Fuel* sub-categories. The objectives of each task are subjectively derived from the task description. Deriving the objectives helps determine what aspects of the task process are required to be measured to develop MOPs. For example, the description for the UNTL task *NTA 4.2.3 Conduct Aerial Refueling* is to "<u>schedule</u> and <u>conduct</u> air to air refueling with refueling tanker aircraft".[Ref.1] The objectives are to properly *schedule* and *conduct* the operation. To determine how well that task is accomplished, the process of *scheduling* and *conducting* aerial refueling must be measured.

In addition to these task descriptions and objectives, the author derives MOEs from the various references to amplify the descriptions

and help identify the ultimate purpose of each task. MOEs describe how effective the CVBG is in combat by accomplishing a task. From the description of the task process, objectives, and MOEs, MOPs are developed. Before listing the derived MOEs and the developed MOPs, a discussion of MOPs and MOEs is first required.

C. DISCUSSION OF MEASURES OF PERFORMANCE AND EFFECTIVENESS

Combining the definitions of "measure" and "performance" from reference [3], a measure of performance is "a basis for evaluation or comparison on the way in which someone or something functions." To apply that definition to a CVBG accomplishing its mission, this thesis defines "measure of performance" as a metric that provides a way for a BGCDR to describe how well the CVBG organization performs a task under a specific set of conditions for a specific mission.

MOPs are used to determine how well a task is performed, to make an existing system work better, and to design and prepare to operate future systems so that they will work better.[Ref.4] Generally, a single MOP is not sufficient to fully address the capabilities of CVBG task performance. Some MOPs may be more relevant, descriptive, and important than others for the specific situation being addressed.

The need to make the distinction between an MOP and MOE is required. MOPs answer the questions, "Did the CVBG perform the task it was supposed to do?" and "How well did the CVBG perform that task?" They describe how well the CVBG met its designed objective. MOEs answer the question, "What is the military value of the CVBG?" They describe the capability of the CVBG to carry out a military task when called upon.[Ref.5]

Ideally, the MOPs and MOEs should be closely linked to make them effective in measuring task performance. If a CVBG satisfies its MOPs, then it should have sufficient capability to carry out its tasks and satisfy its MOEs. Conversely, if the CVBG satisfies its MOEs, it should have sufficient inherent capability to satisfy its MOPs. If MOPs and MOEs are poorly defined and not closely linked, then it is certainly conceivable that a CVBG could execute its assigned tasks very well (e.g., high MOPs) yet have very little military value (e.g., low MOEs) to itself or the entire combat force in winning a battle.[Ref.5] Therefore, MOPs and MOEs must be well defined in order for them to properly serve their function as a measurement and evaluation tool.

This thesis uses the term *quantifiable variable* that will be related to both MOPs and MOEs. Quantifiable variables are quantifiable descriptors of task performance given in terms of time, ratios, quantities, or some other measurable description. A single MOP may depend on one or several of these variables.

For example, an MOP may be the *percent of the needed fuel that was transferred* and depends on the quantifiable variables of the *rate of fuel transfer* and the *amount of fuel to transfer*. Aggregating the variables into a single task descriptor forms the MOP. Figure 2.3 shows the relationship between quantifiable variables, MOPs, and MOEs.

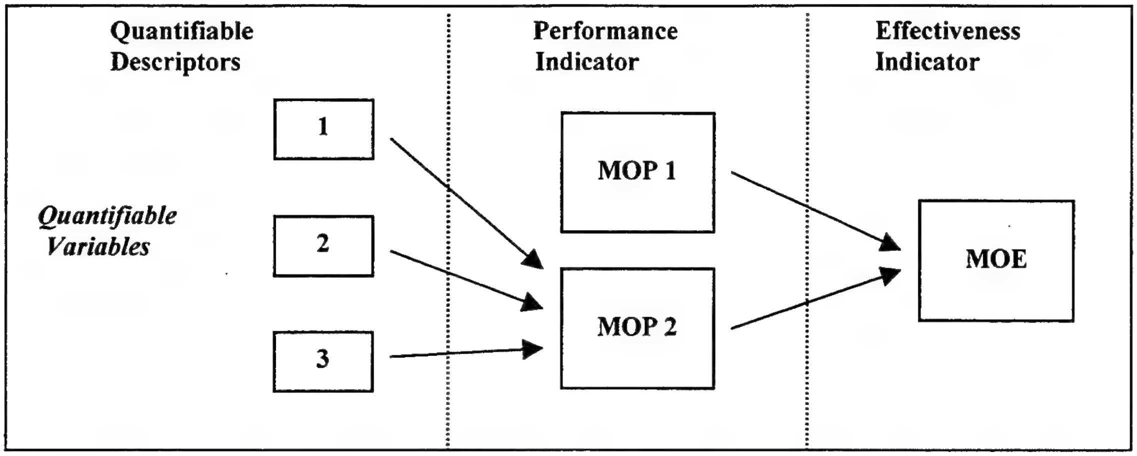

Figure 2.3 Relationship Between Quantifiable Variables, MOPs, and MOEs.

D. ARMAMENT AND FUEL TASK MOES AND MOPS

The author proposes the following MOEs for the tasks:

- NTA 4.1.1 Schedule/Coordinate Armament of Task Force;
  - ♦ *NTA 4.1.1.1 Time Off Station* [Ref.6];
  - ♦ *NTA 4.1.1.2 Percent of Maximum Capacity Experienced* [Ref.6];
- NTA 4.1.2 Provide Munitions Management;
  - ♦ *NTA 4.1.2.1 Percent of Maximum Capacity Experienced* [Ref.6];
  - ♦ *NTA 4.1.2.2 Time Off Station* [Ref.6];
- NTA 4.1.3 Provide Munitions, Pyrotechnics, and Specialty Items;
  - ♦ *NTA 4.1.3.1 Percent of Maximum Capacity Experienced* [Ref.6];
  - ♦ *NTA 4.1.3.2 Time Off Station* [Ref.6];
- NTA 4.2.1 Conduct Fuel Management;
  - ♦ *NTA 4.2.1.1 Time On Station Lost* [Ref.8];
  - ♦ *NTA 4.2.1.2 Percent of Maximum Capacity Experienced* [Ref.6];

- NTA 4.2.2 Schedule/Coordinate Refueling;
    - *NTA 4.2.2.1 Time Off Station* [Ref.6];
    - *NTA 4.2.2.2 Percent of Maximum Capacity Experienced* [Ref.6];
- NTA 4.2.3 Conduct Aerial Refueling;
    - *NTA 4.2.3.1 Number of Aircraft Available to Refuel* [Ref.9];
    - *NTA 4.2.3.2 Number of Aircraft that Could Not Refuel* [Ref.9];
    - *NTA 4.2.3.3 Time On Station* [Ref.10];
- NTA 4.2.4 Move Bulk Fuel;
    - *NTA 4.2.4.1 Time Off Station* [Ref.6];
    - *NTA 4.2.4.2 Percent of Maximum Capacity Experienced* [Ref.6];
- NTA 4.2.5 Provide Packaged Petroleum Products;
    - *NTA 4.2.5.1 Efficiency of Packaging* [Ref.11].

These MOEs are described in Chapter III, and the process of how they are derived is explained in Chapter IV, Section B. These MOEs have associated MOPs. These MOPs are used to define "how well" the task is completed. MOPs are a better measure of task performance when they are related well to their respective MOE. The MOE measures the effectiveness of the task's results in combat. When MOPs and MOEs are completed satisfactorily, the task's utility towards accomplishing mission objectives is high.

Naval Doctrine Command is in the process of defining MOPs to include into the UNTL because the concept of using the UNTL for combat training is new. Because of this ongoing process, the author identified various MOPs based upon a task's objectives and its associated MOEs. The relationship between an MOE with its respective

MOPs is defined by the equations of the MOEs and MOPs in Chapter IV. The following MOPs are recommended for each MOE:

- NTA 4.1.1.1 Time Off Station;
  - *NTA 4.1.1.1.1 Time to Complete the UNREP Evolution;*
  - *NTA 4.1.1.1.2 Time from Request for Ordnance to Commencing UNREP;*
- NTA 4.1.1.2 Percent of Maximum Capacity Experienced;
  - *NTA 4.1.1.2.1 Ratio of the Ordnance Available onboard Shuttle Ships to the CVBG Ordnance Requirements;*
  - *NTA 4.1.1.2.2 Percent of the Needed Ordnance Transferred;*
- NTA 4.1.2.1 Percent of Maximum Capacity Experienced;
  - *NTA 4.1.2.1.1 Ratio of the Ordnance Available onboard Shuttle Ships to the CVBG Ordnance Requirements;*
  - *NTA 4.1.2.1.2 Percent of the Needed Ordnance Transferred;*
- NTA 4.1.2.2 Time Off Station;
  - *NTA 4.1.2.2.1 Time to Complete the UNREP Evolution;*
  - *NTA 4.1.2.2.2 Time from Request for Ordnance to Commencing UNREP;*
- NTA 4.1.3.1 Percent of Maximum Capacity Experienced;
  - *NTA 4.1.3.1.1 Ratio of the Ordnance Available onboard the Shuttle Ships to the Combatant Ships Ordnance Requirements;*
  - *NTA 4.1.3.1.2 Ratio of the Ordnance Available onboard the Shuttle Ships to the Station Ship Ordnance Requirements;*
  - *NTA 4.1.3.1.3 Percent of the Needed Ordnance Transferred;*
- NTA 4.1.3.2 Time Off Station;
  - *NTA 4.1.3.2.1 Time to Complete the UNREP Evolution;*

- ♦ *NTA 4.1.3.2.2 Time from Request for Ordnance to Commencing UNREP;*
- NTA 4.2.1.1 Time On Station Lost;
    - ♦ *NTA 4.2.1.1.1 Percent of the Needed Fuel Quantity Correctly Identified;*
    - ♦ *NTA 4.2.1.1.2 Ratio of the Fuel Available onboard the Shuttle Ships to the CVBG Requirements;*
    - ♦ *NTA 4.2.1.1.3 Percent of the Needed Fuel Transferred;*
- NTA 4.2.1.2 Percent of Maximum Capacity Experienced;
    - ♦ *NTA 4.2.1.2.1 Ratio of the Fuel Available onboard the Shuttle Ships to the CVBG Requirements;*
    - ♦ *NTA 4.2.1.2.2 Percent of the Needed Fuel Transferred;*
- NTA 4.2.2.1 Time Off Station;
    - ♦ *NTA 4.2.2.1.1 Time from the Request for Fuel to Commencing the UNREP;*
    - ♦ *NTA 4.2.2.1.2 Time to Complete the UNREP Evolution;*
- NTA 4.2.2.2 Percent of Maximum Capacity Experienced;
    - ♦ *NTA 4.2.2.2.1 Ratio of the Fuel Available onboard the Shuttle Ships to the CVBG Requirements;*
    - ♦ *NTA 4.2.2.2.2 Percent of the Needed Fuel Transferred;*
- NTA 4.2.3.1 Number of Aircraft Could Have Refueled;
    - ♦ *NTA 4.2.3.1.1 Rate of Fuel Transfer per Tanker Actually Used;*
    - ♦ *NTA 4.2.3.1.2 Time to refuel All Combat Aircraft;*
    - ♦ *NTA 4.2.3.1.3 Ratio of Combat Aircraft per Tanker;*

- NTA 4.2.3.2 Number of Aircraft Could Not Refuel;
  - ♦ *NTA 4.2.3.2.1 Rate of Fuel Transfer per Tanker Actually Used;*
  - ♦ *NTA 4.2.3.2.2 Time to refuel All Combat Aircraft;*
  - ♦ *NTA 4.2.3.2.3 Ratio of Combat Aircraft per Tanker;*
- NTA 4.2.3.3 Time On Station;
  - ♦ *NTA 4.2.3.3.1 Rate of Fuel Transfer Actually Used;*
  - ♦ *NTA 4.2.3.3.2 Ratio of Combat Aircraft per Tanker;*
- NTA 4.2.4.1 Time Off Station;
  - ♦ *NTA 4.2.4.1.1 Time from the Request for Fuel to Commencing the UNREP;*
  - ♦ *NTA 4.2.4.1.2 Time to Complete the UNREP Evolution;*
- NTA 4.2.4.2 Percent of Maximum Capacity Experienced;
  - ♦ *NTA 4.2.4.2.1 Ratio of the Fuel Available onboard the Shuttle Ships to the Combatant Ship Requirements;*
  - ♦ *NTA 4.2.4.2.2 Ratio of the Fuel Available onboard the Shuttle Ships to the Station Ship Requirements;*
  - ♦ *NTA 4.2.4.2.3 Percent of the Needed Fuel Transferred;*
- NTA 4.2.5.1 Efficiency of Packaging;
  - ♦ *NTA 4.2.5.1.1 Percent of Packaged Products Damaged;*
  - ♦ *NTA 4.2.5.1.1 Percent of Packaged Products Improperly Labeled;*
  - ♦ *NTA 4.2.5.1.1 Percent of Packaged Products Found Unusable;*

The relationship between the MOEs and MOPs are defined in the equations provided in Chapter IV. The quantitative analysis of this thesis captures how important these MOPs are to their respective MOEs.

This analysis correlates an MOP and MOE's range of values to determine the strength of their relationship.

Figure A.1 of Appendix A illustrates the relationship among the *Armament* tasks, MOEs, and MOPs. Figure A.2 of Appendix A illustrates the relationship among the *Fuel* tasks, MOEs, and MOPs. The descriptions for each task and their associated MOEs are explained in the next chapter.

E. VARIABLES OF THE MOPS

The measurable variables of a task process are the quantifiable variables. They contribute to MOPs. For each recommended MOP listed in Section D above, the author identifies some quantifiable variables that contribute to them. The variables are listed in Appendix B. Refer to Chapter IV, Sections A and B, as to how the variables are obtained.

F. VALIDATING THE MOPS

This thesis provides recommended MOPs for each *Armament* and *Fuel* logistic task of the UNTL. To assess their usefulness in determining how well a task is accomplished, this thesis applies a qualitative and quantitative analysis to each MOP. The qualitative analysis consists of applying twelve criteria provided by the UNTL to each MOP. Those criteria set the standards for basing a subjective decision of whether the MOP is useful. The quantitative analysis consists of determining the correlation between an MOP and its MOE. By analyzing the correlation coefficient, a more formal determination of how well the MOP measures task performance is established. Explanations of the qualitative and quantitative analyses are described in Chapter IV.

III. CARRIER BATTLE GROUP ORDNANCE AND FUEL TASKS

A. BACKGROUND

The Navy's Carrier Battle Group (CVBG) is a combat formation of ships and aircraft that comprises a principal component of U.S. military power. The "standard" CVBG is one that can provide the initial crisis response mission from a rotationally deployed forward posture. A "standard" CVBG defined by reference [12] contains:

- One Aircraft Carrier
- One Carrier Air Wing
- Six Surface Combatant Ships
- Two Attack Submarines
- One Multi-purpose Logistic Support Ship (e.g., station ship).

The CVBG is able to conduct operations across the spectrum of warfare. It is a powerful asset because it is composed of balanced warfighting and peacekeeping capabilities required to meet the broad range of contingencies faced today.

The U.S. Navy's ability to project power across long ocean distances is bolstered by its ability to sustain itself at sea and assist land forces for prolonged periods mostly without land-based support. Sustainment of fuel and ordnance are the two most critical support elements of this power projection. Embedded in the sustainment process is a logistics pipeline that stretches from the industrial base of the United States to the forward-deployed ships of war. The final stages of these processes consist of the distribution of those assets to the ships. This is accomplished through either replenishment pierside or replenishment at sea.

To properly execute the final stages, intensive training is required. Included in that training process is the execution of logistic tasks taken from the UNTL. Figure 2.1 on page 5 lists the

UNTL sub-categories of CVBG logistics that are crucial to these specific operations. Emphasizing the requirement to train in logistic tasks is one of the thirteen required CVBG tasks defined by the CNO.[Ref.12]

B. ORDNANCE TASKS OF THE UNTL

CVBG ordnance task descriptions are listed verbatim from reference [1] and described below. MOEs described in Chapter II are provided for each task. These MOEs allow the BGCDR to determine various levels of CVBG combat effectiveness. The ultimate purpose for each task is clarified when the MOEs are listed with their task description.

1. NTA 4.1.1 Schedule/Coordinate Armament of Task Force

Task Description: *Schedule and coordinate armament and rearmament of naval/amphibious forces to ensure provision of continued support to forces operating both at sea and ashore. This task includes Replenishment-at-Sea (Underway Replenishment (UNREP)) and from ashore.*

This task considers the ability of shuttle ships to replenish the CVBG (e.g., the combatant ships and the assigned multi-purpose logistic support ship known as the station ship). Refer to figure 3.1. An UNREP is a transfer of liquid or solid cargo between two ships while underway via connected replenishment (CONREP) or vertical replenishment (VERTREP) by helicopter.[Ref.13] Shuttle ships are UNREP capable cargo ships that shuttle between the source of supply and the battle group to replace the actual or planned expenditures of the CVBG.[Ref.8] Shuttle ships are generally single product, e.g., ordnance, fuel, or stores, and must possess the capability to UNREP their products to the CVBG.

Arming the task force includes supplying ordnance for use in a ship's weapon system, aircraft or forces ashore.

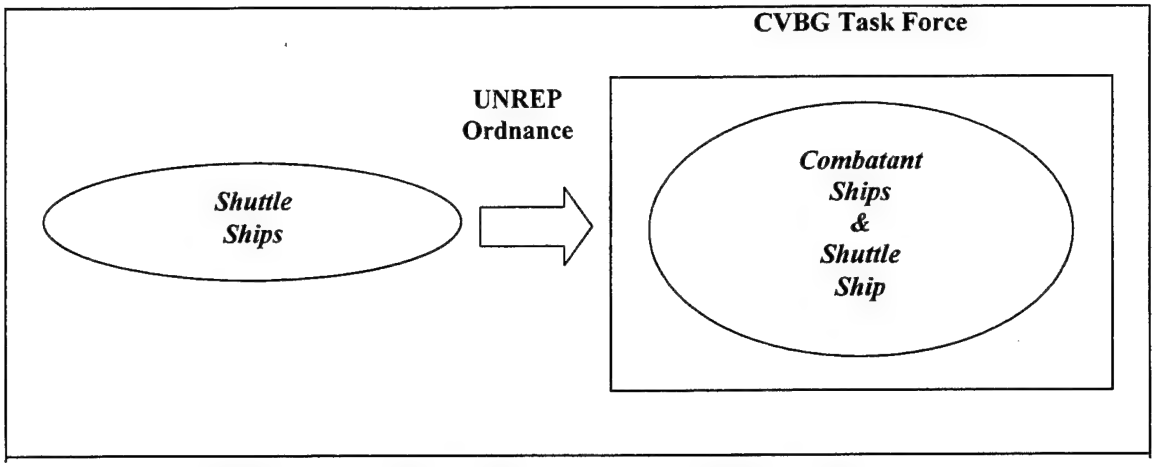

Figure 3.1 Representation of Ordnance Task 1.

There are two MOEs that support this task. The first MOE, *time off station* [Ref.6], is the time not dedicated to the CVBG combat mission. The time that the CVBG spends moving towards the UNREP location and conducting the UNREP is time spent not dedicated to the combat mission.

The second MOE, *percent of maximum capacity experienced* [Ref.6], is the percent difference between the maximum ordnance capacity of the entire CVBG and the minimum ordnance level experienced after ordnance expenditure. This MOE is useful to the BGCDR in comparing where the current CVBG ordnance level falls within acceptable levels.

2. NTA 4.1.2 Provide Munitions Management

Task Description: *To project and allocate available munitions stocks in accordance with combat priorities to weight the main effort.*

Ordnance expenditures are the most difficult to estimate and forecast because they are event driven - conflict-dependent - and thus related dynamically to the nature and scope of a specific combat or exercise engagement.[Ref.14] Major contributors to the dynamic nature of combat and exercises are the conditions in which they occur. The

UNTL provides a listing of those various conditions that may affect ordnance expenditure.

Once ordnance requirements are determined, allocating the ordnance to the CVBG assets is required. This task is similar to the first armament task because it deals with allocating assets via UNREP.

The first MOE, *percent of maximum capacity experienced* [Ref.6], is the percent difference between the maximum ordnance capacity of the entire CVBG and the minimum ordnance level experienced after ordnance expenditure.

The second MOE, *time off station* [Ref.6], is the same as that mentioned for the first ordnance task. This MOE is appropriate because part of the task description is to allocate munitions stock. It describes the time effectiveness of the CVBG's combat effort in allocating additional ordnance via UNREP.

3. NTA 4.1.3 Provide Munitions, Pyrotechnics, and Specialty Items

Task Description: *To supply munitions items such as small arms ammunition, grenades, mines, rockets, missiles, torpedoes, countermeasures, and naval gun, tank and artillery rounds.*

This task incorporates the UNREP system and is similar to the first ordnance task - *Schedule/Coordinate Armament of Task Force.* The difference between the two is that this task considers the shuttle ships directly replenishing the station ship and the combatant ships with the specific munitions type. Figure 3.2 shows what this task does.

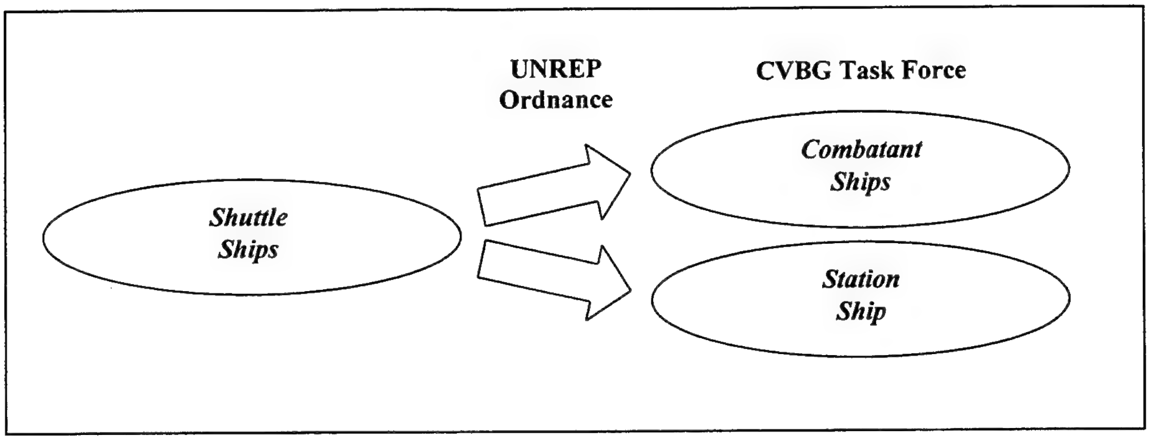

Figure 3.2 Representation of Ordnance Task 3.

The first MOE, *percent of maximum capacity experienced* [Ref.6], is the same as that mentioned for first ordnance task, NTA 4.1.1. It pertains to the minimum ordnance level attained from ordnance expenditure. The MOE is utilized to describe the shuttle ships replenishing either the CVBG's station ship or combatant ships.

The second MOE, *time off station* [Ref.6], is the same as that mentioned for the first ordnance task, NTA 4.1.1. This MOE is appropriate because it describes the time effectiveness of the CVBG's combat effort in allocating additional munitions via UNREP.

C. FUEL TASKS OF THE UNTL

The following CVBG fuel task descriptions are taken verbatim from reference [1]. MOEs are also provided for each task.

1. NTA 4.2.1 Conduct Fuel Management

<u>Task Description</u>: *To monitor and forecast fuel requirements. To manage the distribution of petroleum products based on forecasted unit requirements and availability.*

This task is similar to the ordnance task - *Provide Munitions Management* - because it deals with predicting needs and allocating

assets. Fuel consumption can be more precisely estimated than any other consumable because it is more time-dependent than event-driven.[Ref.14][Ref.15] Petroleum products described here include fuels, oils, lubricants, and greases.[Ref.1]

The first MOE, *time on station lost* [Ref.8], transforms the utility of having fuel available for the CVBG to time units. Forecasting the correct amount of fuel in terms of time that the CVBG requires is a critical element in CVBG mission accomplishment. Underestimating fuel requirements inhibits the ability of the CVBG to remain underway, while overestimating is not as detrimental. This MOE measures the CVBG underway time lost due to forecasting error.

The second MOE, *percent of maximum capacity experienced* [Ref.6], is the percent difference between the maximum fuel capacity summed over the entire CVBG and the minimum fuel level (summed over the entire CVBG) experienced. It pertains to the minimum fuel level attained from being underway. This MOE considers the entire CVBG (e.g., combatant ships and station ship) being replenished by shuttle ships.

2. NTA 4.2.2 Schedule/Coordinate Refueling

Task Description: *Schedule and conduct fueling and replenishment of naval/amphibious forces to ensure provision of continued support to forces operating at sea and ashore. Includes Replenishment-at-Sea (UNREP) and from shore.*

This task is very similar to the task *Schedule/Coordinate Armament of the Task Force*, the primary difference being the resource involved. The resource for this task is fuel. Whether it is fuel for ships or aircraft, this task covers the process of getting that fuel to the CVBG.

The first MOE, *time off station* [Ref.6], is similar to that mentioned for the first ordnance task. It is the time not dedicated to

the CVBG mission due to refueling needs. The second MOE, *percent of maximum capacity experienced* [Ref.6], is the same as that mentioned in the first fuel task.

3. NTA 4.2.3 Conduct Aerial Refueling

Task Description: *Schedule and conduct air-to-air refueling with tanker aircraft.*

Airborne refueling significantly extends the range and endurance of combat aircraft. It increases effective operating tempos and it enhances flexibility in the employment of both land and sea-based aviation forces. Therefore, it is important that the aerial refueling process and the aerial refueling logistics supply pipeline perform well. Appropriate MOPs will help assess the outcome of these processes. With the impending retirement of the KA-6D Intruder, the Navy's primary refueling aircraft, the Navy will rely on the Air Force's KC-135 and KC-10 tankers for tactical airborne refueling support.[Ref.10] The focus here is on how well the KC-135 supports Navy refueling requirements.

The first MOE, *number of aircraft that could have been refueled* [Ref.9], measures how many more combat aircraft could have been refueled for a specific refueling evolution. This MOE compares the rate of fuel transfer actually used to the maximum rate of fuel transfer under the constraints of the time, the number of tankers used, and the amount of fuel carried by the tankers. The results of the MOE give the number of aircraft, in addition to the aircraft originally planned to refuel, that the tankers could have refueled (e.g., 8 aircraft were planned to be refueled; all 8 were refueled plus an additional 3. MOE = 3.)

The second MOE, *number of aircraft that could not be refueled* [Ref.9], accounts for the combat aircraft that could not be refueled

during a specific refueling evolution due to constraints on time, the rate of fuel transfer, and the amount of fuel needed by the combat aircraft. It is closely related to *MOE 1* above except that it measures how many of the originally planned aircraft to refuel could not be refueled (e.g., 8 aircraft were planned to be refueled, but only 6 could be refueled. MOE = 8-6 = 2).

The third MOE, *time on station* [Ref.10], is the time utilized for refueling the combat aircraft based upon the actual fuel transfer rate used. It measures the time difference between a specific refueling evolution and a refueling evolution that uses the maximum possible transfer rate. This MOE is appropriate because time is a critical element in combat. It is important because not every refueling evolution uses the maximum fuel transfer rate.[Ref.10] The MOE will determine the impact on time that results from not using the maximum transfer rate.

4. NTA 4.2.4 Move Bulk Fuel

Task Description: *To move bulk fuels by tankers, rail tank cars, hose lines, or bulk transporters to using or refueling units.*

From the CVBG's perspective, this task describes the process of shuttle ships (i.e., tankers) bringing fuel to the CVBG station ship or combatant ships. This task is very similar to the ordnance task *Provide Munitions, Pyrotechnics, and Specialty Items*. Performance in this task is vital for continual sustainment of the CVBG.

The first MOE, *time off station* [Ref.6], is similar to that mentioned for the first ordnance task. It is the time not dedicated to the CVBG mission due to refueling needs.

The second MOE, *percent of maximum capacity experienced* [Ref.6], is the percent difference between the maximum fuel capacity and the minimum fuel level experienced. It pertains to the minimum fuel level

attained from being underway. This MOE considers the entire CVBG (e.g., combatant ships and station ship) being replenished by shuttle ships.

5. **NTA 4.2.5 Provide Packaged Petroleum Products**

Task Description: *To provide packaged products including lubricants, greases, hydraulic fluids, compressed gases, and specialty items that are stored, transported, and issued in containers with a capacity of 55 gallons or less.*

This task describes the packaging responsibilities for the products listed in the task description. "Packaging" includes preservation-packaging, packing, preparation of unit loads, and the marking of packages and unit loads.[Ref.11] The following definitions taken from reference [11] apply:

- Preservation-Packaging. Application or use of protective measures, including appropriate cleaning and drying methods, preservatives, protective wrappings, cushioning and interior containers, and complete identification marking, up to but not including the exterior pack.
- Packing. Application or use of shipping containers and assembling of packaged or unpackaged items therein, together with necessary blocking, bracing, cushioning, and weatherproofing, plus exterior strapping or reinforcement and marking.
- Unit Load. An assemblage of two or more items (in or out of containers) in a manner designed to permit handling of the items as a single entity using material handling equipment.
- Marking. Application by stamping, painting, or printing of numbers, item name, Federal stock number, symbols or colors on containers, tags, labels, or items for identification during shipment, handling, and storage.

The only MOE, *efficiency in packaging petroleum products* [Ref.11], measures how well the transferred petroleum products are packaged. This MOE compares the perfect packaged products to those

that are determined unusable (i.e., improper preservation-packaging), mislabeled (i.e., improperly marked), and damaged (i.e., poor packing). Most petroleum products are packaged in 12-gallon or 55-gallon steel drums.[Ref.16]

D. CLOSING

This chapter described the ordnance and fuel tasks of the UNTL for a CVBG. MOEs were provided to assist comprehending the ultimate purpose for each task. This should prepare the way for the next chapter: the method used to apply the task descriptions and MOEs from this chapter into an analytic approach to ascertain the quantifiable variables (i.e., the variables that are measurements of task performance) that comprise the MOPs.

IV. METHODOLOGY

This chapter describes the six steps in the process of defining MOPs and determining their usefulness in measuring task performance. The following issues are discussed: (1) the terms objective, MOE, MOP, *quantifiable variable*, and criteria; (2) the twelve criteria used to qualitatively validate the MOPs; (3) a general description of the simulations used to derive data to conduct the quantitative analysis; and (4) the validation of the MOPs.

A. STEPS TO DEVELOP VALID MOPs

The analytic process used for this research is an adaptation of that discussed in reference [17]. This application provides an orderly and systematic procedure to develop MOPs by analyzing the process of each task. The process steps are listed below and described. The steps for each task are as follows:

- *Step 1. Define the <u>Objectives</u> and <u>MOEs</u> of the mission.*
- *Step 2. Select the <u>Quantifiable Variables</u> of the Objectives.*
- *Step 3. Determine the <u>Measures of Performance</u>.*
- *Step 4. Verify the measures of performance against <u>Criteria</u>.*
- *Step 5. Perform <u>Correlation Analysis</u> on the MOPs with their respective MOE.*

1. Step 1 - Objectives and MOEs

Step 1, *Define the <u>Objectives</u> and <u>MOEs</u> of the task*, provides a clear understanding of the purpose(s) of the UNTL ordnance and fuel logistic tasks that are used in determining CVBG performance. The objectives of each task are subjectively derived from the task description taken from the UNTL. To define the MOPs needed to measure

the accomplishment of the objectives, an MOE is defined to associate the MOPs with the objectives. The MOEs used here are those mentioned with the task descriptions described in Chapter III. To illustrate, the description for the UNTL task *Conduct Aerial Refueling* is to "<u>schedule</u> and <u>conduct</u> air to air refueling with refueling tanker aircraft"; the objectives are to properly *schedule* and *conduct* the operation; the MOE may be *time to conduct the refueling evolution (time on station)*.

2. Step 2 - Quantifiable Variables

Step 2, *Select the <u>Quantifiable Variables</u> of the Objectives*, provides the specific characteristics of the task objectives to be measured. Each task process is analyzed to determine what physical measurements are required that would describe the task's performance and achieve its objectives. Those measurements are the quantifiable variables. The MOEs are used to help determine what variables to define. These MOEs link the MOPs and a task's objectives. The quantifiable variables are combined to develop the MOPs. For example, if *conducting an UNREP* is the task's objective and the *percent of maximum capacity experienced* is the MOE, then the quantifiable variables could be the "rate of fuel transfer" and the "amount of fuel to transfer." Both variables are required to describe the task's performance and to achieve the objective. A listing of each task's quantifiable variables is provided in Appendix C.

3. Step 3 - Measures of Performance

Step 3, *Determine the <u>Measures of Performance</u>*, lists the MOPs that have been subjectively determined based upon the quantifiable variables of each task. As mentioned earlier, an MOP is based upon any combination of quantifiable variables (i.e., one or more quantifiable variables can determine an MOP). For example, if the "rate of fuel

transfer" and the "amount of fuel to transfer" are a task's quantifiable variables, then an MOP can be the *percent of the needed fuel that was transferred.* The MOP depends upon both variables, and it describes task performance. A listing of each task's MOPs are provided in Chapter II.

4. Step 4 - Criteria

Step 4, *Verify Measures of Performance against Criteria*, provides twelve criteria taken from the UNTL and used to ensure the MOP selected is valid. The criteria are applied to each MOP developed in Step 3 to ensure it passes a qualitative test (e.g., "common sense test"). Completion of Step 4 answers the first question posed by this thesis, "What measures of performance can be well-defined for each task within the ordnance and fuel logistic sub-categories of the UNTL?" The criteria used are given in Section C of this chapter.

5. Step 5 - Correlation Analysis

Step 5, *Perform Correlation Analysis on the MOPs with their respective MOE*, provides a quantitative basis for validating MOPs. The values of the MOPs are correlated with the values of their MOE to determine any strong relationships between them. Correlation analysis helps to validate that the MOPs accurately describe task performance by comparing their results to those of their respective MOE. A strong correlation implies that an MOP has a strong relationship to its MOE. Details of the process of correlation analysis are described later in this chapter.

The last step quantitatively determines the relationship that an MOP has with its MOE. Therefore, the second question posed by this thesis, "How well do the measures of performance measure task performance?", is answered. Figure 4.1 shows the methodology and the relationship between a task's quantifiable variables, MOP, and MOE.

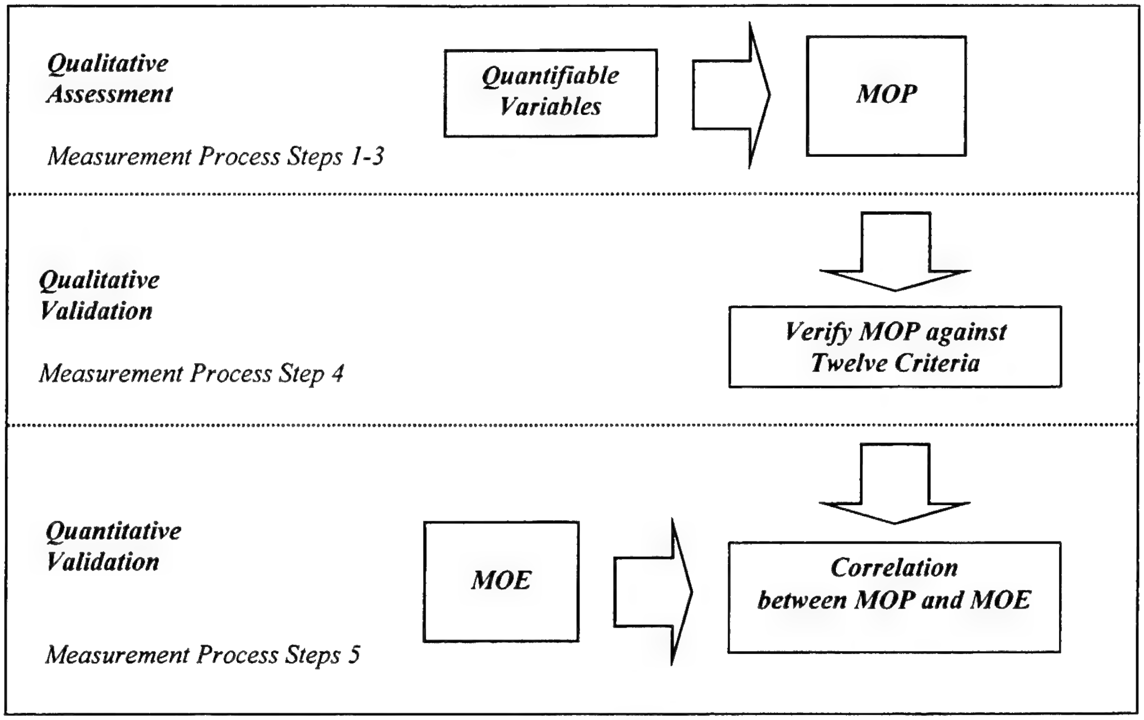

Figure 4.1 MOP Validation Model.

B. DEVELOPING VARIABLES, MOES, AND MOPS

This section intends to further explain how the variables, MOEs, and MOPs are developed. The MOPs determined in Step 3 of the methodology are derived through the following process that includes Step 1 and 2 of the methodology:

- Determine the task's desired objectives;
- Derive MOEs based upon the determined objectives;
- Determine the variables that define the MOE;
- Define MOPs based upon the variables of the MOE.

1. Determine Task Objectives

The UNTL provides the task description for each logistic task. From these descriptions, key words are derived that help determine the objectives for each task. For example, for task *NTA 4.1.3 Provide Munitions, Pyrotechnics, and Specialty Items*, the task description

begins "To supply munitions items. . ." The key word is *supply*. The objective is determined to be *Supply Munitions*. Table 4.1 provides the objectives for each task that are derived from the key words (in bold) of each task description.

Task	*Objectives*
NTA 4.1.1	*1. **Schedule** UNREP* *2. **Coordinate** UNREP*
NTA 4.1.2	*1. **Project** Munitions Stocks* *2. **Allocate** Munitions Stocks*
NTA 4.1.3	*1. **Supply** Munitions*
NTA 4.2.1	*1. **Monitor** Fuel Requirements* *2. **Forecast** Fuel Requirements* *3. **Manage** Fuel Distribution*
NTA 4.2.2	*1. **Schedule** UNREP* *2. **Conduct** UNREP*
NTA 4.2.3	*1. **Schedule** Aerial Refueling* *2. **Conduct** Aerial Refueling*
NTA 4.2.4	*1. **Move** Bulk Fuel*
NTA 4.2.5	*1. **Provide** Packaged Petroleum Products*

Table 4.1 Armament and Fuel Task Objectives.

2. Derive MOEs

MOEs, as discussed in Chapter II, are derived from various references. After determining a task's objective, an MOE is derived to describe how effective that objective is accomplished. For example, to perform a task's objective of *supply munitions*, the CVBG must conduct UNREPs. An MOE of an UNREP can be *Time Off Station*. Chapter III describes the MOEs used for each task. Table 4.2 gives the objectives and MOEs for each armament and fuel task mentioned in Chapter III.

Task	***Objectives***	***MOEs***
NTA 4.1.1	*1. Schedule UNREP* *2. Coordinate UNREP*	*1. Time Off Station* *2. Minimum Level Experienced*
NTA 4.1.2	*1. Project Stocks* *2. Allocate Stocks*	*1. Minimum Level Experienced* *2. Time Off Station*
NTA 4.1.3	*1. Supply Munitions*	*1. Minimum Level Experienced* *2. Time Off Station*
NTA 4.2.1	*1. Monitor Requirements* *2. Forecast Requirements* *3. Manage Distribution*	*1. Time On Station Lost* *2. Minimum Level Experienced*
NTA 4.2.2	*1. Schedule UNREP* *2. Conduct UNREP*	*1. Time Off Station* *2. Minimum Level Experienced*
NTA 4.2.3	*1. Schedule Refueling* *2. Conduct Refueling*	*1. Number of Aircraft Could Have Refueled* *2. Number of Aircraft Could Not be Refueled* *3. Time On Station*
NTA 4.2.4	*1. Move Fuel*	*1. Time Off Station* *2. Minimum Level Experienced*
NTA 4.2.5	*1. Provide Products*	*1. Efficiency of Packaging*

Table 4.2 Task Objectives and MOEs.

3. Determine the Variables of the MOE

This step determines the variables of the MOE that can be measured. These variables are the descriptors of task performance that affect the MOE. These quantifiable variables are provided in Appendix B and C. For example, some of the variables of the MOE *Time Off Station* are the *time until all ships arrive at the UNREP location*, *time to complete UNREP connections*, and *time to disconnect and break-away.* Each variable describes the task performance through the definition of the MOE.

4. Define MOPs from the Variables

MOPs are derived from the quantifiable variables determined from Step 3. An MOP can be a single variable or be comprised of several variables. The MOPs are functions of quantifiable variables to reduce the number of variables into fewer descriptors of task performance. For example, two MOPs defined for the MOE *Time Off Station*, are *Time from Request for Ordnance to Commencing the UNREP* and *Time to Complete the UNREP Evolution.* These two MOPs are comprised of the variables

that help measure the MOE. The relationships used in this thesis between the MOEs, MOPs, and variables are provided in Section D

Once these MOPs are determined, twelve criteria are used to help determine if they are well defined MOPs. The criteria are provided in Section C.

C. DESCRIPTION OF CRITERIA

Criteria described here are taken from the UNTL and used in Step 4 of the methodology. They help ensure that the MOPs selected are useful to the BGCDR in assessing performance by evaluating the MOEs. These criteria complement the quantitative analysis as part of the validation process in selecting MOPs. Using criteria is an intuitive step in any performance evaluation, and applying these criteria to the MOPs will determine what MOPs can be well defined for the tasks. These criterion are not to be confused with the definition of criteria provided on page 6. The criteria explained on page 6 pertain to the assignment of a quantitative value to the MOP description.

The criteria used provide the standards for basing a subjective conclusion on the validity of the MOP developed. They are in the form of a question that demands a "yes" or "no" response. A "yes" response is considered favorable towards validating the MOP. It is not mandatory for all criteria to have a "yes" response to make the MOP completely valid.

The twelve criteria used to help validate MOPs are as follows:

- *Do the MOPs Address a Result or Product of Task Performance?*
- *Do the MOPs Address an Important Dimension of Task Performance?*
- *Do the MOPs Reflect How the Task Contributes to Mission Success?*

- *Do the MOPs Reflect an Aspect of Performance that is Affected by Some Condition(s)?*
- *Do the MOPs Distinguish Among Multiple Levels of Performance?*
- *Can Data on the MOPs be Readily Obtained?*
- *Are the MOPs Independent of the Means Employed to Perform the Task?*
- *Are the MOPs Simple?*
- *Do the MOPs Employ an Absolute Scale?*
- *Do the MOPs Employ a Relative Scale?*
- *Can the MOPs be Interpreted Independent of Mission Context in which they Occurred?*
- *Are the MOPs Controllable?*

D. DESCRIPTION OF THE SIMULATION MODELS

A simulation is used here for Step 5 of the methodology to produce the data necessary to conduct the quantitative analysis between the MOPs and MOEs. This is for illustrative purposes only. The same procedure could be followed with real exercise data. The simulation is designed for each logistic task using Excel 97's Crystal Ball Pro, Version 4.0.[Ref.18] Crystal Ball Pro is a graphical suite of forecasting, risk analysis, and optimization tools for spreadsheet users.

Crystal Ball Pro uses the Monte Carlo simulation technique for producing simulated data. This technique uses a random number generator to produce numbers based upon the probability distribution type and parameters entered for a random variable (e.g., quantifiable variable). The Monte Carlo technique is good for simulating the uncertainty of conditions that exist in the real world.[Ref.18]

1. Designing the Simulation Models

Three steps are taken to design each task's simulation model. Each step is discussed in the next sections.

- Step 1: Assign Distributions. List all of the quantifiable variables onto the spreadsheet and assign a probability distribution for each one.
- Step 2: Assign Parameters. Input the distribution parameters that describe the shape of each assumption variable's probability distribution curve.
- Step 3: Model the MOPs and MOEs. List the MOPs onto the spreadsheet and model them as a function of their associated quantifiable variables. List the MOEs onto the spreadsheet and model them as a function of the MOPs.

2. Steps 1 and 2 - Assigning Distributions and Parameters

Assigning probability distributions and their parameters (e.g., the mean, mode, endpoints, etc.) for the quantifiable variables requires an heuristic procedure due to the absence of full distribution data on the quantifiable variables. The procedure for developing distributions is taken from reference [19] and consists of four steps.

- Step 1. Identify a range [*a*,*b*].
- Step 2. Select a probability distribution on [*a*,*b*] representative of the variable (e.g., quantifiable variable).

An assumption is made that the quantifiable variables are represented by the Beta distribution. The Beta distribution is a good choice to use in simulations in the absence of distribution data because "of the variety of shapes the beta density function can assume." [Ref.19] The Beta distribution proves useful in modeling the behavior of random variables that are positive and bounded in nature. [Ref.20]

Realizing that the Beta distribution is continuous, this thesis uses the approach of rounding the simulation's generated value to the next higher integer for the variables that are discreet by nature. For example, if the model generates a value for the *number of aircraft*

requiring fuel of 7.2786, the model rounds the value to 8. Further calculations are based upon this value.

The Beta distribution can assume shapes similar to the Normal, log Normal, exponential, triangular, and uniform distributions, as well as others. Because of this flexibility and the uncertainty of what the actual distributions are for the data, the Beta distribution is chosen to represent the probability distribution for the quantifiable variables.

- Step 3. Give *subjective* estimates of the unknown parameters (e.g., the mean, μ; the mode, c).

The majority of the values for the mean (μ) and the mode (c) of the quantifiable variables are found in references (8), (9), (10), (13), (14), and (16). For those not available, estimates are used which are based on the experience of the author.

For example, for the task *Conduct Aerial Refueling*, the mean of the quantifiable variable (e.g., *number of aircraft requiring fuel*) is determined from reference [10] to be 5.875 aircraft requiring fuel. The mode is given by reference [10] to be 8 aircraft requiring fuel. For the task *Schedule/Coordinate Armament of Task Force*, the author subjectively sets the mean and mode for the quantifiable variable *speed of the ships used to arrive at the UNREP location* as 20 knots and 15 knots, respectively. Refer to Appendix C for the mean and mode values used in the simulations.

- Step 4. Solve to obtain the following estimates of α_1 and α_2, the Beta distribution's parameters.[Ref.19]

$$\tilde{\alpha}_1 = \frac{(\mu - a)(2c - a - b)}{(c - \mu)(b - a)} \tag{4.1}$$

$$\tilde{\alpha}_2 = \frac{(b - \mu)\tilde{\alpha}_1}{\mu - a} \tag{4.2}$$

A consequence to this heuristic approach for assigning values to the parameters of the Beta distribution is that the values for μ and c cannot be equal. Otherwise, α_1 is undefined. Because μ and c are characteristics of the real world, they may be equal. The Beta distribution can still be used if the mean and mode are equal. The reader must determine values for α_1 and α_2 that describe the shape of the Beta distribution, insert those values into the simulation, and then proceed to run the simulation.

3. Step 3 - Modeling the MOPs and the MOEs

Once the Beta probability distributions are defined from equations 4.1 and 4.2 for each quantifiable variable, they are implemented into Crystal Ball Pro. The MOPs are modeled as functions of the quantifiable variables. Appendix B shows what variables the MOPs use. The functional relationship defined by this thesis between the MOPs and the variables are provided later in this section. The MOEs are modeled as functions of either the (1) variables, (2) variables and MOPs, or (3) MOPs. Their functional relationships defined by this thesis are also provided later in this section. All of these functions are implemented into the model. The model generates values for the quantifiable variables based upon the associated Beta probability distribution. In turn, values are generated for the MOPs and MOEs. Figure 4.2 describes an example of the Crystal Ball simulation output used for the task *Conduct Aerial Refueling*.

The correlation analysis conducted between the values of the MOPs and MOEs serve merely as an example of the methodology because real data obtained on the MOPs include the impact of other variables. A statistical approach is used because (1) the method is simple and

effective, and (2) the analysis of the real data obtained on the values of the MOPs are better analyzed using a statistical approach.

Mean	*Mode*	*Left*	*Right*	Alpha 1	Alpha 2
5.875	8	1	8	2.294118	1
13281	7500	6250	50000	1.146727	5.988717
15.28125	9.5	8.25	32	1.088193	2.587482

Calculated Values

Quantifiable Variables:

Number of Aircraft Requiring Fuel	8	Aircraft
Amount of Fuel Needed per Aircraft	7918.065	Pounds/aircraft
Time to Refuel per Aircraft	24.11366	Minutes/aircraft

MOP:

Fuel Transfer Rate per Tanker	328.3643	Pounds/minute
Time to Refuel all Aircraft	192.9093	Minutes
Ratio of Receivers to Tankers	8	Aircraft/tanker

Simulated Output Data

MOE:

Number of AC Could Have Refueled	39	Aircraft
Time On Station	152.7442	Minutes
Number of AC Could Not Refuel	0	Aircraft

Figure 4.2 One simulation trial in Crystal Ball Pro. The first section shows the input values for the mean, mode, the interval (i.e., *Left* and *Right* endpoints of the range), and the values calculated for α_1 and α_2 (i.e., *Alpha 1* and *Alpha 2*) for the three quantifiable variables. The second section lists the three quantifiable variables and their simulated values generated from their distribution functions. The third and fourth sections list the MOPs and MOEs and their simulated values generated from their functions. 1000 trials are combined to develop distributions of MOPs and MOEs.

Each time a trial is conducted, Crystal Ball Pro uses the Monte Carlo simulation technique to calculate a new value for each quantifiable variable, MOP, and MOE. The equations are shown in later in this section. For each simulation run, 1000 trials are used. Values are calculated for the quantifiable variables, MOPs, and MOEs and empirical probability distributions are determined.

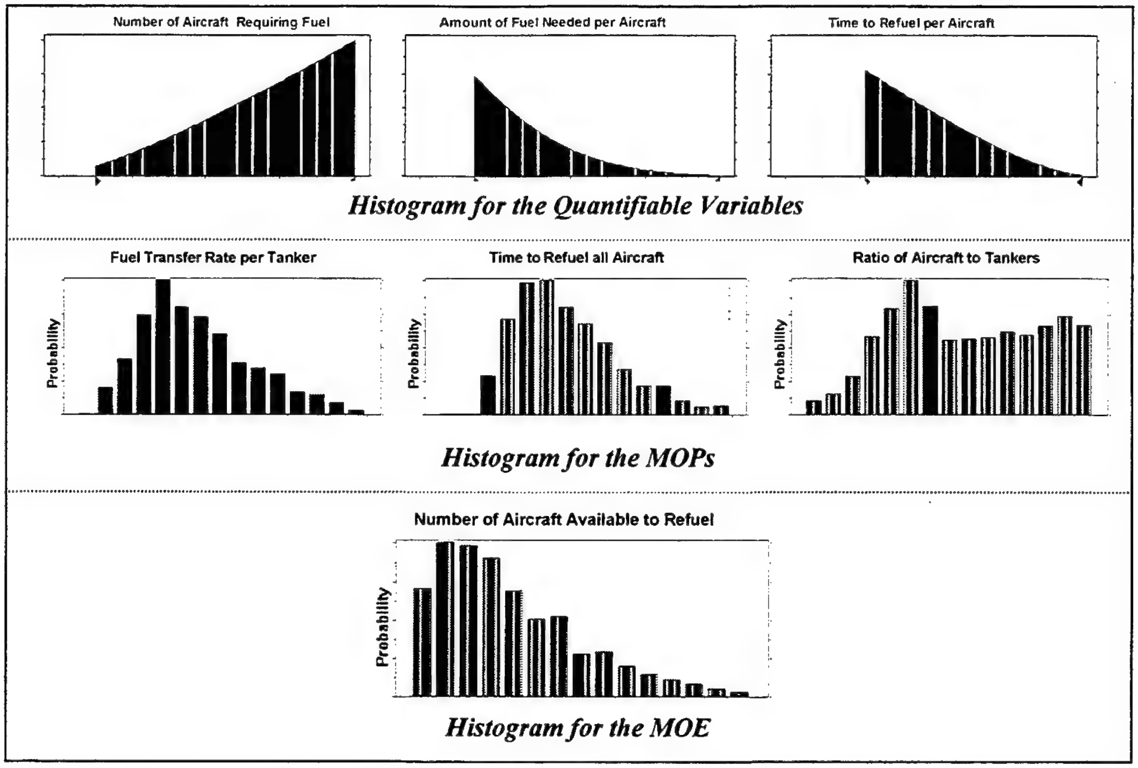

Figure 4.3 Combining Distributions. This figure represents an example of how Crystal Ball Pro displays the probability distributions. The top row of figure 4.3 shows the Beta probability distributions of the quantifiable variables. The middle row shows the simulated distributions of the MOPs. The bottom row shows the simulated distribution of one of the MOEs.

The values obtained for the MOPs and MOEs from the simulations are used to conduct the quantitative analysis. The values of the MOPs are correlated with the MOE values to ascertain any strong relationship. The following sections provide the equations of the MOEs and MOPs used in the simulation. The variables are the quantifiable variables listed in Appendix B and C.

a) *NTA 4.1.1.1 MOE and MOPs*

The MOE *Time Off Station* (TOS_{ORD}) is described in equation 4.3,

$$TOS_{ORD} = TTC_{ORD} + TFR \ , \tag{4.3}$$

where,

TTC_{ORD} = Time to Complete the UNREP Evolution;
TFR = Time from Request for Ordnance to Commencing UNREP.

The MOPs defined for this MOE are as follows:

$$\begin{aligned} TTC_{ORD} = {} & \textit{Time to Repair UNREP Gear} + \textit{Time to Complete UNREP Gear Checks} \\ & + \textit{Time to Repair Helicopter Problems} + \textit{Time Required to Launch Helicopter} \\ & + \textit{Time to Station UNREP Personnel} + \textit{Time to Ready UNREP Gear} \\ & + \textit{Time to Position Ships Alongside} + \textit{Time to Complete UNREP Connections} \\ & + \textit{Time to Stage Ordnance} + \textit{Time to Transfer Ordnance} \\ & + \textit{Time to Breakdown Ordnance} + \textit{Time to Disconnect and Break-Away}; \end{aligned} \tag{4.4}$$

$$\begin{aligned} TFR = {} & \textit{Time to Submit UNREP Request} + \textit{Time to Determine Ordnance Availability} \\ & + \textit{Time to Submit UNREP Order} + \textit{(Distance/Speed) used to Arrive at UNREP Location.} \end{aligned} \tag{4.5}$$

b) *NTA 4.1.1.2 MOE and MOPs*

The MOE *Minimum Level Experienced* (MLE_{ORD}) is described in equation 4.6,

$$MLE_{ORD} = \frac{[CombOrdReq + StatOrdReq - (POX * (CombOrdReq + StatOrdReq))]}{MaxCVBGOrdCap}, \tag{4.6}$$

where,

CombOrdReq = Ordnance Requirements for Combatant Ships;
StatOrdReq = Ordnance Requirements for the Station Ship;
MaxCVBGOrdCap = Maximum Ordnance Capacity of Combatant Ships (700 tons) + Maximum Ordnance Capacity of Station Ship (2100 tons);
POX = Percent of the Needed Ordnance Transferred;

and *POX* is the first MOP defined as

$$POX = \frac{\textit{Amount of Ordnance Transferred}}{CombOrdReq + StatOrdReq}. \tag{4.7}$$

The second MOP used for this MOE is defined as

$$RatioSStoCVBG = \frac{Ordnance\ Available\ on\ the\ Shuttle\ Ship}{CombOrdReq + StatOrdReq}, \qquad (4.8)$$

where,

RatioSStoCVBG = Ratio of the Ordnance Available onboard the Shuttle Ships to the CVBG Ordnance Requirements.

c) NTA 4.1.2.1 MOE and MOPs

This MOE is described by equation 4.6. Refer to Section (b) for the equations used for this MOE and its MOPs.

d) NTA 4.1.2.2 MOE and MOPs

This MOE is described by equation 4.3. Refer to Section (a) for the equations used for this MOE and its MOPs.

e) NTA 4.1.3.1 MOE and MOPs

This MOE is described by equation 4.6. Two MOPs used for this MOE are

$$RatioSStoComb = \frac{Ordnance\ Available\ on\ the\ Shuttle\ Ship}{CombOrdReq}, \qquad (4.9)$$

and

$$RatioSStoStat = \frac{Ordnance\ Available\ on\ the\ Shuttle\ Ship}{StatOrdReq}, \qquad (4.10)$$

where,

RatioSStoComb = Ratio of the Ordnance Available onboard the Shuttle Ships to the Combatant Ship Ordnance Requirements;
RatioSStoStat = Ratio of the Ordnance Available onboard the Shuttle Ships to the Station Ship Ordnance Requirements.

A third MOP used for this MOE is the *Percent of the Needed Ordnance Transferred (POX)*. Refer to equation 4.7.

f) NTA 4.1.3.2 MOE and MOPs

This MOE is described by equation 4.3. Refer to Section (a) for the equations used for this MOE and its MOPs.

g) NTA 4.2.1.1 MOE and MOPs

The MOE *Time On Station Lost (TOSL)* is described in equation 4.11,

$$TOSL = \frac{\{(CombFuelReq + StatFuelReq) - (PFID * [CombFuelReq + StatFuelReq])\}}{Combatant\ Ship's\ Fuel\ Usage\ Rate + Station\ Ship's\ Usage\ Burn\ Rate}, \quad (4.11)$$

where,

CombFuelReq = Fuel Requirements for Combatant Ships;
StatFuelReq = Fuel Requirements for the Station Ship;
Combatant Ship's Fuel Usage Rate = 6,300 barrels/day;
Combatant Ship's Fuel Usage Rate = 900 barrels/day;

and *PFID* is the first MOP defined as

$$PFID = \frac{Amount\ of\ Fuel\ Correctly\ Identified}{CombFuelReq + StatFuelReq}, \quad (4.12)$$

where,

PFID = Percent of the Needed Fuel Quantity Correctly Identified.

The second MOP used for this MOE is defined as

$$FuelRatioSStoCVBG = \frac{Fuel\ Available\ on\ the\ Shuttle\ Ship}{CombFuelReq + StatFuelReq}, \quad (4.13)$$

where,

FuelRatioSStoCVBG = Ratio of the Fuel Available Onboard the Shuttle Ships to the CVBG Requirements.

The third MOP used for this MOE is defined as

$$PFX = \frac{Amount\ of\ Fuel\ Transferred}{CombFuelReq + StatFuelReq}, \quad (4.14)$$

where,

PFX = Percent of the Needed Fuel Transferred.

h) NTA 4.2.1.2 MOE and MOPs

The MOE *Minimum Level Experienced* (MLE_{FUEL}) is described in equation 4.15,

$$MLE_{FUEL} = \frac{[CombFuelReq + StatFuelReq - (PFX * (CombFuelReq + StatFuelReq))]}{MaxCVBGFuelCap}, \qquad (4.15)$$

where,

MaxCVBGFuelCap = Maximum Fuel Capacity of Combatant Ships (60,000 barrels) + Maximum Fuel Capacity of Station Ship (10,250 barrels).

The MOPs used for this MOE are *FuelRatioSStoCVBG* and *PFX*. Refer to equations 4.13 and 4.14.

i) NTA 4.2.2.1 MOE and MOPs

The MOE *Time Off Station* (TOS_{FUEL}) is described in equation 4.16,

$$TOS_{FUEL} = TTC_{FUEL} + TFR \,, \qquad (4.16)$$

where,

$$\begin{aligned} TTC_{FUEL} = {} & \textit{Time to Repair UNREP Gear} + \textit{Time to Complete UNREP Gear Checks} \\ & + \textit{Time to Repair Helicopter Problems} + \textit{Time Required to Launch Helicopter} \\ & + \textit{Time to Station UNREP Personnel} + \textit{Time to Ready UNREP Gear} \\ & + \textit{Time to Position Ships Alongside} + \textit{Time to Complete UNREP Connections} \\ & + \textit{(Amount of Fuel to Transfer/Fuel Transfer Rate)} \\ & + \textit{Time to Disconnect and Break-Away}, \qquad (4.17) \end{aligned}$$

$$\begin{aligned} TFR = {} & \textit{Time to Submit UNREP Request} + \textit{Time to Determine Fuel Availability} \\ & + \textit{Time to Submit UNREP Order} + \textit{(Distance/Speed) used to Arrive at UNREP Location}, \qquad (4.18) \end{aligned}$$

are the MOPs defined for this MOE;

TTC_{FUEL} = Time to Complete the UNREP Evolution;
TFR = Time from Request for Fuel to Commencing the UNREP.

j) NTA 4.2.2.2 MOE and MOPs

This MOE is described in equation 4.15. Refer to Section (h) for the equations used for this MOE and its MOPs.

k) *NTA 4.2.3.1 MOE and MOPs*

The MOE *Number of Aircraft Could Have Refueled (NACHR)* is described in equation 4.19,

$$NACHR = \frac{MFTR - AFTR}{RATIO_{AC/Tanker}} * TTR * \frac{ACRefuel}{FuelAC}, \tag{4.19}$$

where,

MFTR = Maximum Fuel Transfer Rate Possible (2,000 lbs/min);
ACRefuel = Number of Aircraft Requiring Fuel;
FuelAC = Amount of Fuel Needed per Aircraft.

The MOPs used are *AFTR*, $RATIO_{AC/Tanker}$, and *TTR* and are defined as

$$AFTR = \frac{FuelAC}{(Time\ to\ Refuel\ per\ Aircraft) * (Number\ of\ Tankers\ Needed)}, \tag{4.20}$$

$$RATIO_{AC/Tanker} = \frac{ACRefuel}{Number\ of\ Tankers\ Needed}, \tag{4.21}$$

$$TTR = (ACRefuel) * (Time\ to\ refuel\ per\ Aircraft), \tag{4.22}$$

where,

AFTR = Rate of Fuel Transfer per Tanker Actually Used;
$RATIO_{AC/Tanker}$ = Ratio of Combat Aircraft per Tanker;
TTR = Time to Refuel All Combat Aircraft.

This MOE measures the number of aircraft that can be refueled in addition to the originally planned aircraft. The MOE compares the maximum fuel transfer rate possible for the tankers to the fuel transfer rate actually used under the constraints of *ACRefuel*, *FuelAC*, and the time allotted to refuel per aircraft.

The model proceeds with the *NACHR* calculations under the constraint $AFTR < MFTR$. When $AFTR \geq MFTR$, the model assigns the value of zero to *NACHR* because the tanker's fuel transfer rate has reached the maximum rate possible; no additional aircraft can be refueled.

l) NTA 4.2.3.2 MOE and MOPs

The MOE *Number of Aircraft Could Not be Refueled (NACNR)* is described in equation 4.23,

$$NACNR = \frac{AFTR - MFTR}{RATIO_{AC/Tanker}} * TTR * \frac{ACRefuel}{FuelAC}. \quad (4.23)$$

The MOE is measuring the number of aircraft that could not be refueled under the constraints of *ACRefuel*, *FuelAC*, and the time allotted to refuel per aircraft. When the refueling evolution is constrained by these variables, the model calculates the actual fuel transfer rate required to refuel all aircraft needing fuel and satisfy those constraints. The model then compares that value to the maximum fuel transfer rate possible by the tankers to determine how many aircraft could not be refueled.

The model proceeds with the *NACNR* calculations under the constraint $AFTR > MFTR$. When $AFTR \leq MFTR$, the model assigns the value of zero to *NACHR* because the actual fuel transfer rate required to refuel all aircraft is within the acceptable transfer rate possible. As long as the required transfer rate is less than the maximum transfer rate possible, all aircraft can be refueled. The MOPs are *AFTR*, $RATIO_{AC/Tanker}$, and *TTR*. Refer to Section (k).

m) NTA 4.2.3.3 MOE and MOPs

The MOE *Time On Station (TONS)* is described in equation 4.24,

$$TONS = \left[\frac{(ACRefuel)*(FuelAC)}{(Number\ of\ Tankers\ Needed)*(AFTR)}\right] - \left[\frac{(ACRefuel)*(FuelAC)}{(Number\ of\ Tankers\ Needed)*(MFTR)}\right]. \quad (4.24)$$

The MOE is measuring the time difference between the fuel transfer rate actually used to the maximum transfer rate possible. The model assigns the value of zero to *TONS* when $AFTR \geq MFTR$ because the transfer rate actually used has reached its maximum possible value; no time is lost when the maximum fuel transfer rate is used.

n) NTA 4.2.4.1 MOE and MOPs

This MOE is described in equation 4.16. Refer to Section (i) for the equations used for this MOE and its MOPs.

o) NTA 4.2.4.2 MOE and MOPs

This MOE is described in equation 4.15. Two MOPs are

$$FuelRatioSStoComb = \frac{Fuel\ Available\ on\ the\ Shuttle\ Ship}{CombFuelReq}, \tag{4.25}$$

$$FuelRatioSStoStat = \frac{Fuel\ Available\ on\ the\ Shuttle\ Ship}{StatFuelReq}, \tag{4.26}$$

where,

FuelRatioSStoComb = Ratio of the Fuel Available Onboard the Shuttle Ships to the Combatant Ship Requirements;
FuelRatioSStoStat = Ratio of the Fuel Available Onboard the Shuttle Ships to the Combatant Ship Requirements.

The third MOP is *PFX*. Refer to equation 4.14.

p) NTA 4.2.5.1 MOE and MOPs

The MOE *Efficiency of Packaging (EOP)* is described in equation 4.27,

$$EOP = 1 - (PPD + PPI + PPU), \tag{4.27}$$

where,

$$PPD = \frac{Number\ of\ 55\text{-}gallon\ Drums\ Damaged + Number\ of\ 12\text{-}gallon\ Drums\ Damaged}{Number\ of\ 55\text{-}gallon\ Drums\ Needed + Number\ of\ 12\text{-}gallon\ Drums\ Needed}, \tag{4.28}$$

$$PPI = \frac{Number\ of\ 55\text{-}gallon\ Drums\ Improperly\ Labeled + Number\ of\ 12\text{-}gallon\ Drums\ Improperly\ Labeled}{Number\ of\ 55\text{-}gallon\ Drums\ Needed + Number\ of\ 12\text{-}gallon\ Drums\ Needed}, \tag{4.29}$$

$$PPU = \frac{Number\ of\ 55\text{ - }gallon\ Drums\ Found\ Unusable + Number\ of\ 12\text{ - }gallon\ Drums\ Found\ Unusable}{Number\ of\ 55\text{ - }gallon\ Drums\ Needed + Number\ of\ 12\text{ - }gallon\ Drums\ Needed},$$

(4.30)

are the MOPs defined for this MOE;

PPD = Percent of Packaged Products Damaged;
PPI = Percent of Packaged Products Improperly Labeled;
PPU = Percent of Packaged Products Found Unusable.

E. CORRELATION ANALYSIS

Correlation analysis, Step 5 of the methodology, measures the linear relationship between two random variables, i.e., the MOE and MOP. Computing a correlation coefficient ($\rho_{x,y}$) does this. Crystal Ball Pro calculates the correlation coefficient between every MOP and its associated MOE by using the following equation:

$$\rho_{x,y} = \frac{n\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{\sqrt{n\sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2} * \sqrt{n\sum_{i=1}^{n} y_i^2 - \left(\sum_{i=1}^{n} y_i\right)^2}}$$

where,

n = number of trials, indexed by i;

x_i = variable of the MOP;

y_i = variable of the MOE.

Correlation coefficients range between ±1.0. It is a number that describes the relative strengths of the linear relationship between the MOP and MOE. Because this thesis defines the MOPs and MOEs through functions, the MOPs and MOEs do correlate. The purpose of the correlation analysis is to determine the strength of the MOP-MOE relationship. This determination helps understand how well the MOP measures task performance relative to the MOE defined for that task.

From reference [21], the following criteria determines the nominal strength of that relationship:

- $|\rho_{x,y}| < 0.50$ $\Rightarrow$ *Weak correlation;*
- $0.50 \leq |\rho_{x,y}| < 0.80$ $\Rightarrow$ *Moderate correlation;*
- $0.80 \leq |\rho_{x,y}| < 1.00$ $\Rightarrow$ *Strong correlation.*

The correlation coefficient is not an indication of causality. It merely gives an indication that a relationship between an MOP and MOE exists. That relationship shows that if there are changes in the MOP, then there is a change in the MOE.[Ref.22]

F. CLOSING

This chapter presented the methodology used to define and validate MOPs. Not only are the MOPs assessed against twelve criteria as defined in the UNTL, they are also quantitatively assessed against MOEs to determine their utility as a measurement tool. The next chapter provides the results of the qualitative analysis (i.e., the validation against the criteria) and quantitative analysis. The determination of how good the MOPs are in measuring task performance is made based upon the results of the analyses.

V. DATA RESULTS AND ANALYSIS

This chapter provides the results of the qualitative analysis conducted on the MOPs and the results of the quantitative analysis (e.g., correlation analysis) between each MOP and its MOE for each *Armament* and *Fuel* task.

A. RESULTS OF THE ARMAMENT TASKS

The criteria referenced in Step 4 of the methodology in Chapter IV are applied to the measures of performance defined for each *Armament* task. Table 5.1 shows how each MOP meets the methodology's criteria. A mark (•) indicates that the MOP does meet the criterion (i.e., the MOP answers "Yes" to the criterion). As mentioned in Chapter IV, a MOP does not have to meet every criterion to be valid in measuring CVBG performance, but a more valid MOP will meet more criteria. Because of what criterion 9 and 10 ask, either criterion 9 or 10 has to be marked. Refer to Chapter IV for the listing of each criterion.

MOP No.	*Criterion Number*											
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
NTA 4.1.1.1.1	•	•	•	•	•	•	•	•	•		•	•
NTA 4.1.1.1.2	•	•	•	•	•	•	•	•	•		•	•
NTA 4.1.1.2.1		•	•	•	•	•	•	•		•	•	•
NTA 4.1.1.2.2	•	•	•	•	•	•	•	•		•	•	•
NTA 4.1.2.1.1		•	•	•	•	•	•	•		•	•	•
NTA 4.1.2.1.2	•	•	•	•	•	•	•	•		•	•	•
NTA 4.1.2.2.1	•	•	•	•	•	•	•	•	•		•	•
NTA 4.1.2.2.2	•	•	•	•	•	•	•	•	•		•	•
NTA 4.1.3.1.1		•	•	•	•	•	•	•		•	•	•
NTA 4.1.3.1.2		•	•	•	•	•	•	•		•	•	•
NTA 4.1.3.1.3	•	•	•	•	•	•	•	•		•	•	•
NTA 4.1.3.2.1	•	•	•	•	•	•	•	•	•		•	•
NTA 4.1.3.2.2	•	•	•	•	•	•	•	•	•		•	•

Table 5.1 Results of the Qualitative Analysis - How the Armament MOPs Met the Criteria.

Table 5.2 displays (1) the results of the correlation analyses conducted on the MOPs to their respective MOE, and (2) the significance of each MOP in measuring task performance based upon the criteria assigned to the correlation coefficient in Chapter IV, Section E.

	Correlation Coefficient	*Level of Significance*
MOE No. NTA 4.1.1.1		
MOP No. NTA 4.1.1.1.1	*+ 0.85*	*Strong*
MOP No. NTA 4.1.1.1.2	*+ 0.36*	*Weak*
MOE No. NTA 4.1.1.2		
MOP No. NTA 4.1.1.2.1	*+ 0.95*	*Strong*
MOP No. NTA 4.1.1.2.2	*+ 1.00*	*Strong*
MOE No. NTA 4.1.2.1		
MOP No. NTA 4.1.2.1.1	*+ 0.95*	*Strong*
MOP No. NTA 4.1.2.1.2	*+ 1.00*	*Strong*
MOE No. NTA 4.1.2.2		
MOP No. NTA 4.1.2.2.1	*+ 0.85*	*Strong*
MOP No. NTA 4.1.2.2.2	*+ 0.36*	*Weak*
MOE No. NTA 4.1.3.1		
MOP No. NTA 4.1.3.1.1	*+ 0.43*	*Weak*
MOP No. NTA 4.1.3.1.2	*+ 0.45*	*Weak*
MOP No. NTA 4.1.3.1.3	*+ 0.84*	*Strong*
MOE No. NTA 4.1.3.2		
MOP No. NTA 4.1.3.2.1	*+ 0.85*	*Strong*
MOP No. NTA 4.1.3.2.2	*+ 0.36*	*Weak*

Table 5.2 Quantitative Analysis Between the Armament Task MOEs and MOPs.

B. RESULTS OF THE FUEL TASKS

The criteria referenced in Step 4 of the methodology in Chapter IV are applied to the measures of performance defined for each fuel task. Table 5.3 shows how each MOP meets the methodology's criteria.

Table 5.4 displays (1) the results of the correlation analyses conducted on MOPs to their respective MOE, and (2) the significance of each MOP in measuring task performance based upon the criteria assigned to the correlation coefficient in Chapter IV, Section E.

Note that for the same fuel task, an MOP may describe task performance through one or more MOEs. For example, for the first fuel

task, the MOEs *NTA 4.2.1.1* and *NTA 4.2.1.2* have two of the same MOPs. Because these MOPs define their respective MOE in a different context, the *correlation coefficients* and *contributions to variance* are different.

MOP No.	*Criterion Number*											
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
NTA 4.2.1.1.1	•	•	•		•	•		•		•	•	•
NTA 4.2.1.1.2		•	•	•	•	•	•	•		•	•	•
NTA 4.2.1.1.3	•	•	•	•	•	•	•	•		•	•	•
NTA 4.2.1.2.1		•	•	•	•	•	•	•		•	•	•
NTA 4.2.1.2.2	•	•	•	•	•	•	•	•		•	•	•
NTA 4.2.2.1.1	•	•	•	•	•	•	•	•	•		•	•
NTA 4.2.2.1.2	•	•	•	•	•	•	•	•	•		•	•
NTA 4.2.2.2.1		•	•	•	•	•	•	•		•	•	•
NTA 4.2.2.2.2	•	•	•	•	•	•	•	•		•	•	•
NTA 4.2.3.1.1	•	•	•	•	•	•	•	•		•	•	•
NTA 4.2.3.1.2	•	•	•	•	•	•	•	•	•		•	•
NTA 4.2.3.1.3		•	•	•	•	•	•	•		•	•	•
NTA 4.2.3.2.1	•	•	•	•	•	•	•	•		•	•	•
NTA 4.2.3.2.2	•	•	•	•	•	•	•	•	•		•	•
NTA 4.2.3.2.3		•	•	•	•	•	•	•		•	•	•
NTA 4.2.3.3.1	•	•	•	•	•	•	•	•		•	•	•
NTA 4.2.3.3.2		•	•	•	•	•	•	•		•	•	•
NTA 4.2.4.1.1	•	•	•	•	•	•	•	•		•	•	•
NTA 4.2.4.1.2	•	•	•	•	•	•	•	•		•	•	•
NTA 4.2.4.2.1	•	•	•	•	•	•	•	•		•	•	•
NTA 4.2.4.2.2	•	•	•	•	•	•	•	•	•		•	•
NTA 4.2.4.2.3	•	•	•	•	•	•	•	•	•		•	•
NTA 4.2.5.1.1	•	•	•	•	•	•	•	•		•	•	•
NTA 4.2.5.1.2	•	•	•	•	•	•	•	•		•	•	•
NTA 4.2.5.1.3	•	•	•	•	•	•	•	•		•	•	•

Table 5.3 Results of the Qualitative Analysis - How the Fuel MOPs Met the Criteria.

	Correlation Coefficient	Level of Significance
MOE No. NTA 4.2.1.1		
MOP No. NTA 4.2.1.1.1	- 0.98	Strong
MOP No. NTA 4.2.1.1.2	- 0.74	Moderate
MOP No. NTA 4.2.1.1.3	- 0.90	Strong
MOE No. NTA 4.2.1.2		
MOP No. NTA 4.2.1.2.1	+ 0.76	Moderate
MOP No. NTA 4.2.1.2.2	+ 1.00	Strong
MOE No. NTA 4.2.2.1		
MOP No. NTA 4.2.2.1.1	+ 0.48	Weak
MOP No. NTA 4.2.2.1.2	+ 0.77	Moderate
MOE No. NTA 4.2.2.2		
MOP No. NTA 4.2.2.2.1	+ 0.76	Moderate
MOP No. NTA 4.2.2.2.2	+ 1.00	Strong
MOE No. NTA 4.2.3.1		
MOP No. NTA 4.2.3.1.1	- 0.90	Strong
MOP No. NTA 4.2.3.1.2	+ 0.83	Strong
MOP No. NTA 4.2.3.1.3	+ 0.39	Weak
MOE No. NTA 4.2.3.2		
MOP No. NTA 4.2.3.2.1	+ 0.03	Weak
MOP No. NTA 4.2.3.2.2	+ 0.02	Weak
MOP No. NTA 4.2.3.2.3	- 0.02	Weak
MOE No. NTA 4.2.3.3		
MOP No. NTA 4.2.3.3.1	- 0.83	Strong
MOP No. NTA 4.2.3.3.2	+ 0.41	Weak
MOE No. NTA 4.2.4.1		
MOP No. NTA 4.2.4.1.1	+ 0.48	Weak
MOP No. NTA 4.2.4.1.2	+ 0.77	Moderate
MOE No. NTA 4.2.4.2		
MOP No. NTA 4.2.4.2.1	+ 0.67	Moderate
MOP No. NTA 4.2.4.2.3	+ 1.00	Strong
MOE No. NTA 4.2.5.1		
MOP No. NTA 4.2.5.1.1	- 0.63	Moderate
MOP No. NTA 4.2.5.1.2	- 0.97	Strong
MOP No. NTA 4.2.5.1.3	- 0.82	Strong

Table 5.4 Quantitative Analysis Between the Fuel Task MOEs and MOPs.

C. ANALYSIS OF THE MOPS

1. Analysis of MOPs against Criteria

Tables 5.1 and 5.3 in Chapter V show how the *Armament* and *Fuel* task MOPs met the criteria provided in Chapter IV, Section C. Even though the tables give the results of a qualitative analysis based upon a subjective determination of how the MOPs met the criteria, they serve as a guideline for determining a well-defined MOP (i.e., the MOP is a good descriptor to use in measuring task performance). The more criteria met (i.e., as indicated by the black dot) indicates a well-defined MOP. Not all criteria need to be met to be a well-defined MOP. Also, either criterion 9 or 10 is marked, not both. Refer to the criterion listed in Chapter IV, Section C. When checking to see if an MOP met all criteria, the fact that either criterion 9 or 10 is marked is taken into account.

The following four *Armament* task MOPs did not meet all criterion:

- NTA 4.1.1.2.1 Ratio of Ordnance Available onboard Shuttle Ships to the CVBG Ordnance Requirements;
- NTA 4.1.2.1.1 Ratio of Ordnance Available onboard Shuttle Ships to the CVBG Ordnance Requirements;
- NTA 4.1.3.1.1 Ratio of Ordnance Available onboard Shuttle Ships to the Combatant Ships' Ordnance Requirements;
- NTA 4.1.3.1.2 Ratio of Ordnance Available onboard Shuttle Ships to the Station Ship's Ordnance Requirements.

The following seven *Fuel* task MOPs did not meet all criterion:

- NTA 4.2.1.1.1 Percent of the Fuel Quantity Correctly Identified;
- NTA 4.2.1.1.2 Ratio of the Fuel Available onboard Shuttle Ships to the CVBG Requirements;
- NTA 4.2.1.2.1 Ratio of the Fuel Available onboard Shuttle Ships to the CVBG Requirements;
- NTA 4.2.2.2.1 Ratio of the Fuel Available onboard Shuttle Ships to the CVBG Requirements;
- NTA 4.2.3.1.3 Ratio of Combat Aircraft per Tanker;
- NTA 4.2.3.2.3 Ratio of Combat Aircraft per Tanker;
- NTA 4.2.3.3.2 Ratio of Combat Aircraft per Tanker.

All of these MOPs dealt with ratios except for *NTA 4.2.1.1.1*. The MOPs that are defined by a ratio did not satisfy Criterion 1, which focuses on an MOP measuring a task's result and not the task's process. These MOPs focus on inputs or resources (e.g., the number of aircraft involved in conducting aerial refueling) involved as opposed to the outputs or results of the task's performance.

The MOP *Percent of the Fuel Quantity Correctly Identified* did not satisfy Criterion 4, which focuses upon the MOP's ability to be affected by external conditions of the environment. This MOP does not account for any external conditions when predicting the amount of fuel required for the CVBG. An MOP is more useful to the CVBG if it has the ability to be influenced by the external conditions that are factors of the real world.

2. Analysis of MOPs Correlated with MOEs

Tables 5.2 and 5.4 in Chapter V show how the values of the *Armament* and *Fuel* task MOPs correlated with their respective MOE. The MOPs determined to be useful meet either the *strong* or *moderate* criteria for the correlation coefficient (see Chapter IV, Section E).

The following five *Armament* task MOPs have a *weak* correlation with their MOE:

- NTA 4.1.1.1.2 Time from Request for Ordnance to Commencing UNREP;
- NTA 4.1.2.2.2 Time from Request for Ordnance to Commencing UNREP;
- NTA 4.1.3.1.1 Ratio of Ordnance Available onboard Shuttle Ships to the Combatant Ships' Ordnance Requirements;
- NTA 4.1.3.1.2 Ratio of Ordnance Available onboard Shuttle Ships to the Station Ship's Ordnance Requirements;
- NTA 4.1.3.2.2 Time from Request for Ordnance to Commencing UNREP.

The MOPs *Time from Request for Ordnance to Commencing UNREP* have little correlation with their MOE of *Time Off Station* because the values of the time variables of the MOP are not great enough to affect

the range of values for the MOE. The MOE does not respond significantly enough with changes in the values of the MOP to be considered a good MOP.

The MOPs *NTA 4.1.3.1.1* and *4.1.3.1.2* have *weak* correlation with their MOE of *Percent of Maximum Capacity Experienced* because when the ordnance requirements of the combatant ships and the station ship are considered individually, they do not represent the true ordnance requirement of the entire CVBG. When the ordnance requirements are considered as a single quantity (e.g., *CVBG ordnance requirements = combatant ship ordnance requirements + station ship ordnance requirements*), then the true ordnance requirement is represented.

The following seven *Fuel* task MOPs have a *weak* correlation with their MOE:

- NTA 4.2.2.1.1 Time from Request for Fuel to Commencing the UNREP;
- NTA 4.2.3.1.3 Ratio of Combat Aircraft per Tanker;
- NTA 4.2.3.2.1 Rate of Fuel Transfer per Tanker Actually Used;
- NTA 4.2.3.2.2 Time to Refuel All Combat Aircraft;
- NTA 4.2.3.2.3 Ratio of Combat Aircraft per Tanker;
- NTA 4.2.3.3.2 Ratio of Combat Aircraft per Tanker;
- NTA 4.2.4.1.1 Time from Request for Fuel to Commencing the UNREP.

The MOPs *Time from Request for Fuel to Commencing the UNREP* have little correlation with their MOE of *Time Off Station* for the same reason of the *Armament* task MOP of *Time from Request for Ordnance to Commencing UNREP* as explained earlier.

The MOP *Ratio of Combat Aircraft per Tanker* had *weak* correlation with its MOE because the simulation primarily uses one tanker per refueling evolution. One tanker is enough to meet the fuel demand of the all the aircraft requiring fuel. Therefore, the ratio did not change significantly enough to give good correlation between the MOP and the MOE.

The MOPs *Rate of Fuel Transfer per Tanker Actually Used* and *Time to Refuel All Combat Aircraft* had *weak* correlation to their MOE of *Number of Aircraft that Could Not be Refueled* because the simulation primarily produced values of the MOE equal to zero (i.e., the number of aircraft that could not be refueled per evolution = 0). The tankers had enough fuel, enough time, and a fuel transfer rate that enabled all combat aircraft to be refueled in most refueling evolutions.

3. Analysis of Criteria versus Correlation

The qualitative analysis (i.e., verifying MOPs against the twelve criterion) reveals no MOP having significant problems in being considered a well-defined MOP. Only one MOP did not meet two of the criterion, ten MOPs did not meet one of the criterion, and the remaining 26 MOPs met all criterion.

The quantitative analysis (i.e., correlating the values of an MOP with the values of its MOE) gives a better indication of how well the MOPs measure task performance. Even though the qualitative analysis helped determine what MOPs can be well-defined, it is the quantitative analyses that proved very useful in rating each MOP with a *strong*, *moderate*, or *weak* description for measuring task performance.

There is no direct relationship between the MOPs that did not meet a criterion to the MOPs with *weak* correlation. The difference lies in the fact that one analysis is strictly subjective and the other is more formal in its approach (i.e., use of equations and a statistical analysis). To determine a well-defined and useful MOP, no conclusion is made by directly comparing the two analyses.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The purpose of this thesis is to determine measures of performance for the *Armament* and *Fuel* logistic tasks designated in the UNTL for a CVBG. This thesis answers two questions, "What measures of performance can be well-defined for each task within the armament and fuel sub-category of the *NTA 4 Perform Logistics and Combat Service Support* tactical level hierarchical listing?", and "How well do those measures of performance measure task performance?"

The conclusions of this thesis are: (1) the 37 MOPs listed in Chapter II are defined for the *Armament* and *Fuel* logistic tasks; (2) based upon the qualitative analysis, all of the proposed MOPs are well-defined measures of task performance; and (3) based upon the quantitative analysis, only 25 of the 37 MOPs are useful in measuring task performance.

B. RECOMMENDATIONS FOR USING THE MOPS

Using the UNTL and the NMETL development process is a new concept. Though this thesis listed applicable measures of performance for the given logistic tasks, there needs to be continual improvements and modifications made to them with their use in CVBG combat exercises. Three steps need to be done for that to occur. First, a database needs to be maintained by each CVBG on what tasks and MOPs from the UNTL were selected and exercised. Second, the database needs to include the BGCDR's criteria set to the MOPs and the actual outcome performed by the CVBG in terms of MOEs. Third, comparisons need to be made between the set criteria and the actual outcomes. The evaluation of the results between the actual outcomes and the set criteria can determine

if the BGCDR's set criteria or the MOPs selected are the cause of any variations in the expected task's outcome.

C. AREAS FOR FUTURE STUDY

This thesis covers two of thirteen sub-categories of the UNTL's logistic category, *NTA 4 Perform Logistics and Combat Service Support*. The remaining eleven sub-categories or the sub-categories of the other five mission objective categories can be approached in the same manner for future research.

This thesis also gave recommended MOPs based upon the MOEs defined for each task. These MOPs and MOEs are not all inclusive. Other MOEs can be defined for the tasks. These different MOEs provide different MOPs.

Further analysis can be conducted on the relationship between the MOPs and MOEs. Specifically, multiple regression of the MOPs on the MOEs can help provide more information on their relationships.

Once the MOPs are fully integrated into CVBG exercises and databases have been established, there can be future research into the needed modifications of the MOPs used. With the availability of actual data, better analysis can be made on the recommended MOPs of this thesis or on the determination of other MOPs.

APPENDIX A. TASK, MOE, AND MOP RELATIONSHIPS

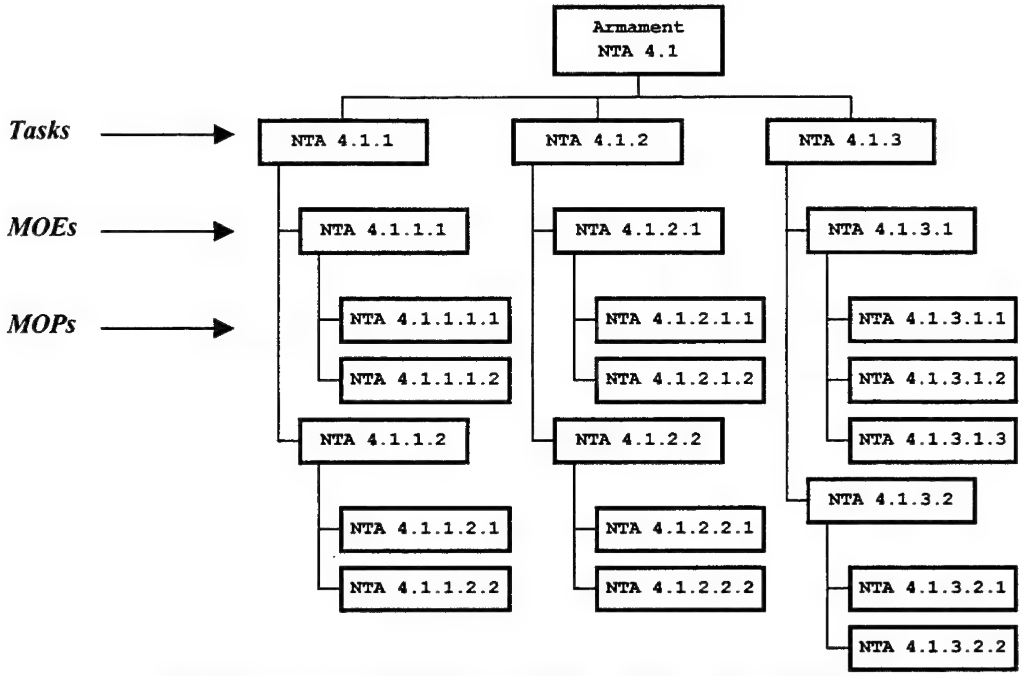

Figure A.1 Armament Tasks, MOEs, and MOPs.

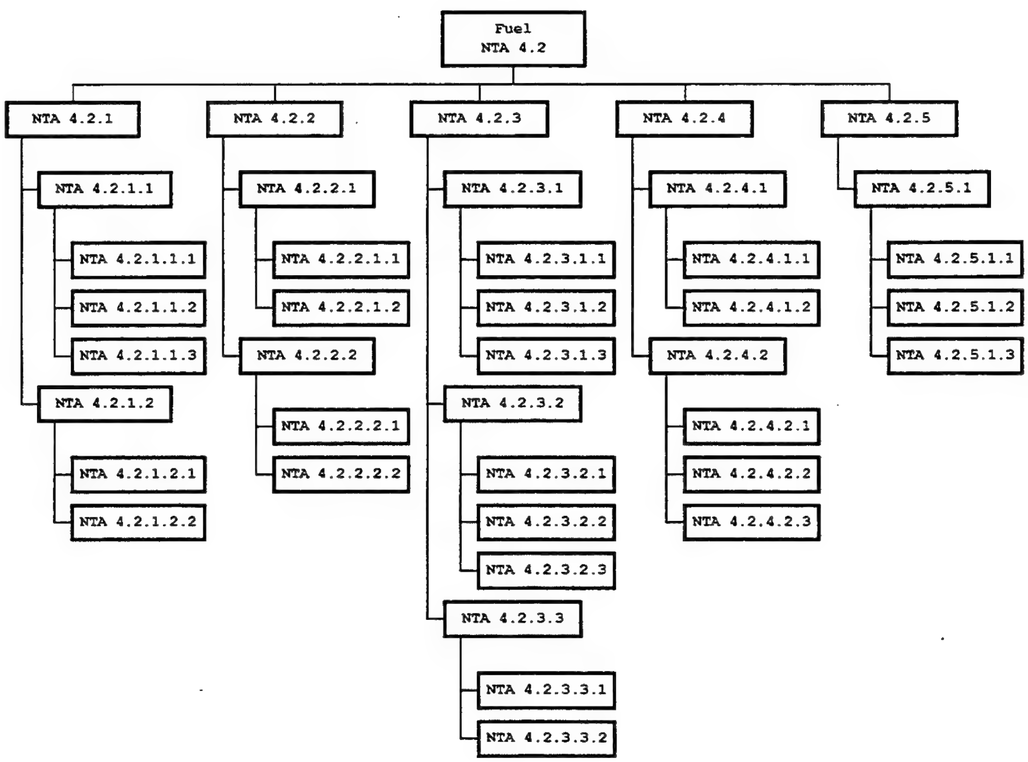

Figure A.2 Fuel Tasks, MOEs, and MOPs.

APPENDIX B. QUANTIFIABLE VARIABLES FOR THE MOPS

The quantifiable variables for each *Armament* and *Fuel* task are listed below.

Quantifiable Variable	*Measures of Performance that use this Variable*
Ordnance Requirements for Combatant Ships (tons)	*NTA 4.1.1.2.1, NTA 4.1.1.2.2, NTA 4.1.2.1.1, NTA 4.1.2.1.2, NTA 4.1.3.1.1, NTA 4.1.3.1.3*
Ordnance Requirements for the Station Ship (tons)	*NTA 4.1.1.2.1, NTA 4.1.1.2.2, NTA 4.1.2.1.1, NTA 4.1.2.1.2, NTA 4.1.3.1.2, NTA 4.1.3.1.3*
Ordnance Available on the Station Ship (tons)	*NTA 4.1.2.1.1, NTA 4.1.3.1.1, NTA 4.1.3.1.2*
Ordnance Available on the Shuttle Ship (tons)	*NTA 4.1.2.1.1, NTA 4.1.3.1.1, NTA 4.1.3.1.2*
Time to Submit UNREP Request (minutes)	*NTA 4.1.1.1.2, NTA 4.1.2.2.2, NTA 4.1.3.2.2, NTA 4.2.2.1.2, NTA 4.2.4.1.2*
Time to Determine Ordnance or Fuel Availability (minutes)	*NTA 4.1.1.1.2, NTA 4.1.2.2.2, NTA 4.1.3.2.2, NTA 4.2.2.1.2, NTA 4.2.4.1.2*
Time to Submit UNREP Order (minutes)	*NTA 4.1.1.1.2, NTA 4.1.2.2.2, NTA 4.1.3.2.2, NTA 4.2.2.1.2, NTA 4.2.4.1.2*
Distance to the UNREP Location (nautical miles)	*NTA 4.1.1.1.2, NTA 4.1.2.2.2, NTA 4.1.3.2.2, NTA 4.2.2.1.2, NTA 4.2.4.1.2*
Speed used to Arrive at UNREP Location (knots)	*NTA 4.1.1.1.2, NTA 4.1.2.2.2, NTA 4.1.3.2.2, NTA 4.2.2.1.2, NTA 4.2.4.1.2*
Time until Moving Towards UNREP Location (minutes)	*NTA 4.1.1.1.2, NTA 4.1.2.2.2, NTA 4.1.3.2.2, NTA 4.2.2.1.2, NTA 4.2.4.1.2*
Time until All Ships Arrive at UNREP Location (minutes)	*NTA 4.1.1.1.1, NTA 4.1.2.2.1, NTA 4.1.3.2.1, NTA 4.2.2.1.1, NTA 4.2.4.1.1*
Time to Repair UNREP Gear (minutes)	*NTA 4.1.1.1.1, NTA 4.1.2.2.1, NTA 4.1.3.2.1, NTA 4.2.2.1.1, NTA 4.2.4.1.1*
Time to Complete UNREP Gear Checks (minutes)	*NTA 4.1.1.1.1, NTA 4.1.2.2.1, NTA 4.1.3.2.1, NTA 4.2.2.1.1, NTA 4.2.4.1.1*
Time to Repair Communications (minutes)	*NTA 4.1.1.1.1, NTA 4.1.2.2.1, NTA 4.1.3.2.1, NTA 4.2.2.1.1, NTA 4.2.4.1.1*
Time to Complete Communication Checks (minutes)	*NTA 4.1.1.1.1, NTA 4.1.2.2.1, NTA 4.1.3.2.1, NTA 4.2.2.1.1, NTA 4.2.4.1.1*
Time to Repair Helicopter Problems (minutes)	*NTA 4.1.1.1.1, NTA 4.1.2.2.1, NTA 4.1.3.2.1, NTA 4.2.2.1.1, NTA 4.2.4.1.1*
Time Required to Launch Helicopter (minutes)	*NTA 4.1.1.1.1, NTA 4.1.2.2.1, NTA 4.1.3.2.1, NTA 4.2.2.1.1, NTA 4.2.4.1.1*
Time to Station UNREP Personnel (minutes)	*NTA 4.1.1.1.1, NTA 4.1.2.2.1, NTA 4.1.3.2.1, NTA 4.2.2.1.1, NTA 4.2.4.1.1*
Time to Ready UNREP Gear (minutes)	*NTA 4.1.1.1.1, NTA 4.1.2.2.1, NTA 4.1.3.2.1, NTA 4.2.2.1.1, NTA 4.2.4.1.1*
Time to Position Ships Alongside (minutes)	*NTA 4.1.1.1.1, NTA 4.1.2.2.1, NTA 4.1.3.2.1, NTA 4.2.2.1.1, NTA 4.2.4.1.1*
Time to Complete UNREP Connections (minutes)	*NTA 4.1.1.1.1, NTA 4.1.2.2.1, NTA 4.1.3.2.1, NTA 4.2.2.1.1, NTA 4.2.4.1.1*
Time to Stage Ordnance (minutes)	*NTA 4.1.1.1.1, NTA 4.1.2.2.1, NTA 4.1.3.2.1*

Quantifiable Variable	*Measures of Performance that use this Variable*
Time to Breakdown Ordnance (minutes)	*NTA 4.1.1.1.1, NTA 4.1.2.2.1, NTA 4.1.3.2.1*
Time to Disconnect and Break-Away (minutes)	*NTA 4.1.1.1.1, NTA 4.1.2.2.1, NTA 4.1.3.2.1, NTA 4.2.2.1.1, NTA 4.2.4.1.1*
Amount of Ordnance Transferred (tons)	*NTA 4.1.1.2.2, NTA 4.1.2.1.2, NTA 4.1.3.1.3*
Percent of Ordnance Requirements Correctly Identified using Models (%)	*NTA 4.1.2.1.1*
Percent of Ordnance Requirements Correctly Identified using Experience (%)	*NTA 4.1.2.1.1*
Probability of Combat Kill by an Ordnance Type (%)	*NTA 4.1.2.1.1*
Probability of Combat Engagement by an Ordnance Type (%)	*NTA 4.1.2.1.1*
Amount of Fuel Required by the Combatant Ships (barrels)	*NTA 4.2.1.1.1, NTA 4.2.1.1.2, NTA 4.2.1.1.3, NTA 4.2.1.2.1, NTA 4.2.1.2.2, NTA 4.2.2.2.1, NTA 4.2.2.2.2, NTA 4.2.4.2.1, NTA 4.2.4.2.2*
Amount of Fuel Required by the Station Ship (barrels)	*NTA 4.2.1.1.1, NTA 4.2.1.1.2, NTA 4.2.1.1.3, NTA 4.2.1.2.1, NTA 4.2.1.2.2, NTA 4.2.2.2.1, NTA 4.2.2.2.2, NTA 4.2.4.2.1, NTA 4.2.4.2.2*
Amount of Fuel Available on the Station Ship (barrels)	*NTA 4.2.1.1.1, NTA 4.2.1.1.2, NTA 4.2.1.1.3, NTA 4.2.1.2.1, NTA 4.2.1.2.2, NTA 4.2.2.2.1, NTA 4.2.2.2.2, NTA 4.2.4.2.1, NTA 4.2.4.2.2*
Amount of Fuel Available on the Shuttle Ship (barrels)	*NTA 4.2.1.1.1, NTA 4.2.1.1.2, NTA 4.2.1.1.3, NTA 4.2.1.2.1, NTA 4.2.1.2.2, NTA 4.2.2.2.1, NTA 4.2.2.2.2, NTA 4.2.4.2.1, NTA 4.2.4.2.2*
Amount of Fuel Transferred (barrels)	*NTA 4.2.1.1.3, NTA 4.2.1.2.2, NTA 4.2.2.2.2, NTA 4.2.4.2.2*
Amount of Fuel Correctly Identified (%)	*NTA 4.2.1.1.1*
Number of Aircraft Requiring Fuel	*NTA 4.2.3.1.2, NTA 4.2.3.1.3, NTA 4.2.3.2.2, NTA 4.2.3.2.3, NTA 4.2.3.3.2*
Amount of Fuel Needed per Aircraft (pounds/aircraft))	*NTA 4.2.3.1.1, NTA 4.2.3.1.2, NTA 4.2.3.2.1, NTA 4.2.3.2.2, NTA 4.2.3.3.1*
Time Taken to Refuel each Aircraft (minutes/aircraft)	*NTA 4.2.3.1.2, NTA 4.2.3.1.3, NTA 4.2.3.2.2, NTA 4.2.3.2.3, NTA 4.2.3.3.2*
Number of 55-gallon Drums Needed	*NTA 4.2.5.1.1, NTA 4.2.5.1.2, NTA 4.2.5.1.3*
Number of 12-gallon Drums Needed	*NTA 4.2.5.1.1, NTA 4.2.5.1.2, NTA 4.2.5.1.3*
Number of Damaged 55-gallon Drums	*NTA 4.2.5.1.1*
Number of Damaged 12-gallon Drums	*NTA 4.2.5.1.1*
Number of Improperly Marked 55-gallon Drums	*NTA 4.2.5.1.2*
Number of Improperly Marked 12-gallon Drums	*NTA 4.2.5.1.2*
Number of Unusable 55-gallon Drums	*NTA 4.2.5.1.3*
Number of Unusable 12-gallon Drums	*NTA 4.2.5.1.3*

APPENDIX C. BETA DISTRIBUTION PARAMETERS

This appendix lists the parameters used to describe the Beta distributions of the quantifiable variables used in the simulations.

Quantifiable Variable	Mean	Mode	Left Bound	Right Bound
Ordnance Requirements for Combatant Ships (tons)	204.6	186	0	700
Ordnance Requirements for the Station Ship (tons)	362.25	315	0	2,100
Ordnance Available on the Station Ship (tons)	1,517.25	1,785	0	2,100
Ordnance Available on the Shuttle Ship (tons)	5,800	6,000	0	6,500
Time to Submit Ordnance Request (minutes)	45	30	15	60
Time to Determine Ordnance Availability (minutes)	45	30	15	60
Time to Submit UNREP Order (minutes)	45	30	15	60
Distance to the UNREP Location (nautical miles)	15	10	0	50
Speed used to Arrive at UNREP Location (knots)	20	15	15	25
Time until Moving Towards UNREP Location (minutes)	45	30	0	120
Time until All Ships Arrive at UNREP Location (minutes)	30	20	0	60
Time to Repair UNREP Gear (minutes)	20	15	0	60
Time to Complete UNREP Gear Checks (minutes)	45	30	5	60
Time to Repair Communications (minutes)	30	15	0	60
Time to Complete Communication Checks (minutes)	15	10	5	30
Time to Repair Helicopter Problems (minutes)	15	0	0	60
Time Required to Launch Helicopter (minutes)	30	25	10	60
Time to Station UNREP Personnel (minutes)	40	30	10	60
Time to Ready UNREP Gear (minutes)	40	30	10	60
Time to Position Ships Alongside (minutes)	5	3	1	15
Time to Complete UNREP Connections (minutes)	25	20	5	45
Time to Stage Ordnance (minutes)	45	30	15	60
Time to Breakdown Ordnance (minutes)	45	30	15	60
Time to Disconnect and Break-Away (minutes)	45	30	15	60
Amount of Ordnance Transferred (tons)	(note 1)	(note 2)	0	(note 3)

Quantifiable Variable	*Mean*	*Mode*	*Left Bound*	*Right Bound*
Percent of Ordnance Requirements Correctly Identified using Models (%)	*85*	*90*	*0*	*100*
Percent of Ordnance Requirements Correctly Identified using Experience (%)	*70*	*75*	*0*	*100*
Probability of Combat Kill by an Ordnance Type (%)	*80*	*85*	*0*	*100*
Probability of Combat Engagement by an Ordnance Type (%)	*80*	*90*	*0*	*100*
Amount of Fuel Required by the Combatant Ships (barrels)	*5,280*	*4,800*	*0*	*60,000*
Amount of Fuel Required by the Station Ship (barrels)	*990*	*900*	*0*	*10,250*
Amount of Fuel Available on the Station Ship (barrels)	*123,900*	*132,750*	*0*	*177,000*
Amount of Fuel Available on the Shuttle Ship (barrels)	*84,000*	*90,000*	*0*	*120,000*
Amount of Fuel Transferred (barrels)	*(note 4)*	*(note 5)*	*0*	*(note 6)*
Amount of Fuel Correctly Identified (%)	*(note 7)*	*(note 8)*	*0*	*(note 9)*
Number of Aircraft Requiring Fuel	*5.875*	*8*	*1*	*8*
Amount of Fuel Needed per Aircraft (pounds/aircraft))	*13,281*	*7,500*	*6,250*	*50,000*
Time Taken to Refuel each Aircraft (minutes/aircraft)	*15.3*	*9.5*	*8.25*	*32*
Number of 55-gallon Drums Needed	*250*	*200*	*1*	*500*
Number of 12-gallon Drums Needed	*250*	*200*	*1*	*500*
Number of Damaged 55-gallon Drums	*(note 10)*	*(note 11)*	*0*	*(note 12)*
Number of Damaged 12-gallon Drums	*(note 10)*	*(note 11)*	*0*	*(note 12)*
Number of Improperly Marked 55-gallon Drums	*(note 10)*	*(note 11)*	*0*	*(note 12)*
Number of Improperly Marked 12-gallon Drums	*(note 10)*	*(note 11)*	*0*	*(note 12)*
Number of Unusable 55-gallon Drums	*(note 10)*	*(note 11)*	*0*	*(note 12)*
Number of Unusable 12-gallon Drums	*(note 10)*	*(note 11)*	*0*	*(note 12)*

Note 1. 95% of the total ordnance required.

Note 2. 100% of the total ordnance required.

Note 3. Equal to the total amount of ordnance required by the CVBG.

Note 4. 95% of the total amount of fuel required.

Note 5. Equal to the total amount of fuel required.

Note 6. Equal to the total amount of fuel required.

Note 7. 90% of the Mode.

Note 8. 90% of the total amount of fuel required.

Note 9. Equal to the total amount of fuel required.

Note 10. 15% of the total number of drums needed.

Note 11. 10% of the total number of drums needed.

Note 12. Equal to the total number of drums needed.

LIST OF REFERENCES

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GLOSSARY OF DEFINITIONS

Condition. Those variables of an operational environment or situation in which a unit, system, or individual is expected to operate that may affect performance.

Connected Replenishment (CONREP). A horizontal transfer via connected replenishment rigs of liquid and/or solid cargo between two ships while underway.

Criterion or Criteria. A rule, test, or quantitative value on which a judgment or decision can be based.

Forecast Variable. A variable of the simulation model that is a function of the assumption variables. Forecast variable is a term used to define the measure of effectiveness (MOE) that has been implemented into the simulation model.

Logistics Weighted Combat Value. The concept that describes the additional marginal combat value of a resource added to the Carrier Battle Group as a function of time.

Measure. A dimension, capacity, or quantity description to a task. A measure provides the basis for describing varying levels of task performance. Measure is used interchangeably with Measure of Performance (MOP).

Measure of Effectiveness (MOE). A metric that describes military worth or value. A measure of effectiveness is an indicator of a task's performance upon effective combat operations.

Measure of Performance (MOP). A metric that provides a way for a commander to describe how well an organization, system, or individual must perform a task under a specific set of conditions for a specific mission.

Mission. The task, together with the purpose, that clearly indicates the action to be taken and the reason therefor.

Mission Essential Task (MET). A task selected by a commander from the Universal Naval Task List (UNTL) deemed essential to mission accomplishment.

Mission Essential Task List (METL). A list of tasks considered essential to the accomplishment of assigned or anticipated missions.

Navy Mission Essential Task List (NMETL). A list of Navy tasks considered essential to the accomplishment of assigned or anticipated missions.

Quantifiable Variable. Quantifiable variables comprise MOPs. They are quantifiable descriptors of task performance given in terms of time, ratios, quantities, or some other measurable description.

Shuttle Ship. An UNREP capable cargo ship that shuttles between the source of supply and the battle group to replace the actual or planned expenditures of the CVBG. Shuttle ships are generally single product, e.g., fuel, ordnance, or stores.

Standard. The minimum acceptable proficiency required in the performance of a particular task under a set of conditions. It is defined by a commander and consists of measure and criteria.

Station Ship. An UNREP capable ship that is a member of a carrier battle group (CVBG) to replace the actual or planned expenditures of the CVBG. Station ships are multi-product, e.g., fuel and ordnance and stores.

Task. A discrete event or action, not specific to a single unit, weapon system, or individual, that enables a mission or function to be accomplished by individuals and/or organizations.

Underway Replenishment (UNREP). A transfer of liquid and/or solid cargo between two ships while underway. Two methods of transfer are employed: horizontal transfer via connected replenishment rigs and vertical replenishment via helicopter.

Universal Naval Task List (UNTL). A comprehensive hierarchical listing of the tasks that can be performed by a naval force, describes the variables in the environment that can affect the performance of a given task, and provides the measures of performance that can be applied by a commander to a set a standard of expected values.

Vertical Replenishment (VERTREP). A vertical transfer via helicopter of liquid and/or solid cargo between two ships while underway.

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